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METAL CONGRESS AND NATIONAL METAL EXPOSITION

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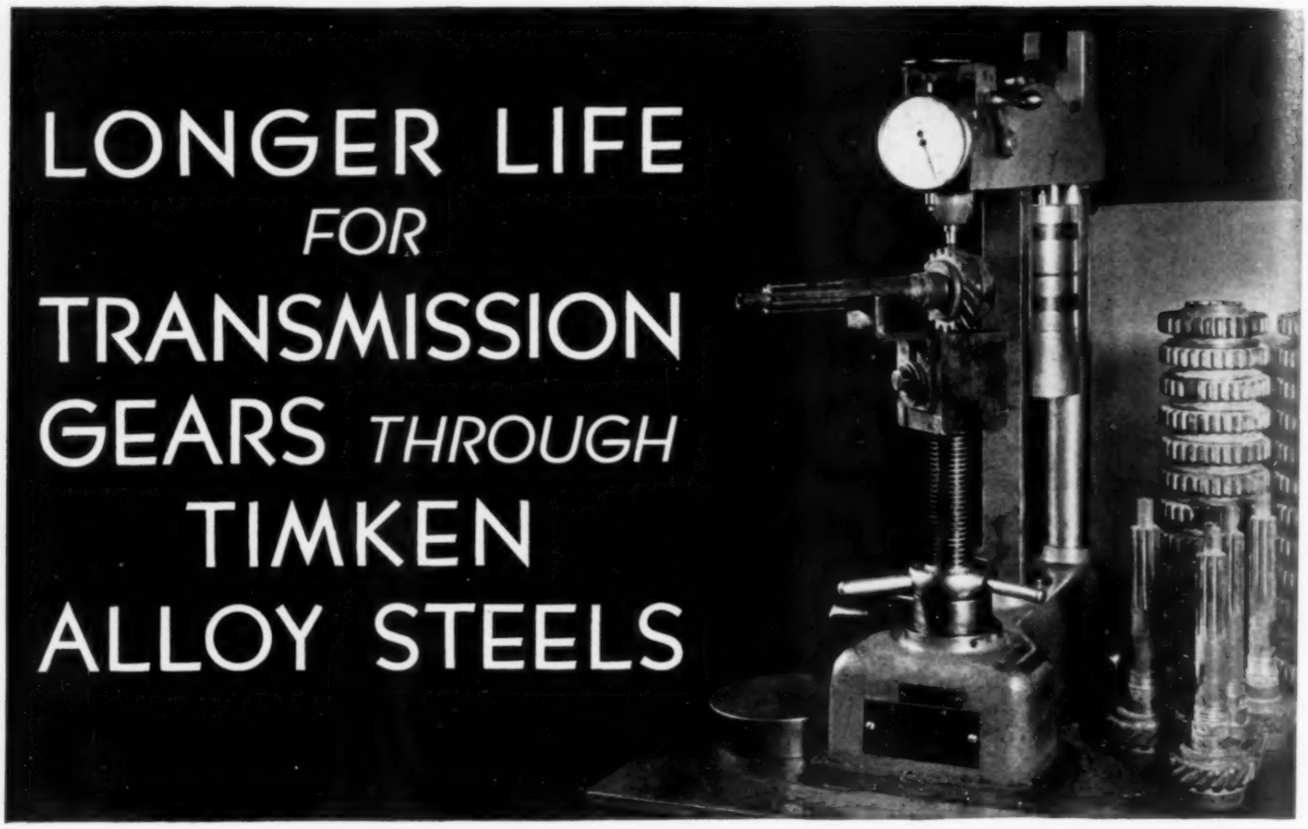
Ernest E. Thum, Editor.



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The Ubiquitous Stainless Steels

By John A. Mathews, Vice President,
Crucible Steel Co. of America

ALLOY MODIFICATIONS OF 18-8

IN ACCEPTING an invitation to discuss alloy modifications of the well-known 18% chromium, 8% nickel stainless steel, it is difficult to decide how far afield one should go. 18-8 itself is a "modification" of the older Krupp V2A alloy (which may be represented by 20% chromium, 6% nickel). It is of interest that in this country, at least, the "modifications" antedate the "type," for the earliest oxidation resistant steels made by Charles M. Johnson at the Park Works, Pittsburgh, contained silicon as an essential constituent. These investigations, started early in 1917, explored the field between 18 and 20% chromium and 5 to 12% nickel with additions of various other elements. Based on his work, an alloy later known as "Rezistal No. 2" was developed — the 18-8 ratio of chromium and nickel plus 2 to 3% silicon.

Of late years many varieties of 18-8 have been developed for special applications. It is not simply a case of "adding this to that"; it requires experience and research. In all cases it is a matter of suitably balanced proportions of carbon, nickel, chromium, and some other metal. For example, with given carbon:chromium:nickel ratios, increasing silicon promotes the formation of delta iron. With very low carbon, even 1.0% may suffice, while with high carbon (0.20%), even 3.5% silicon may prove ineffective, while increasing the nickel or the carbon lessens the tendency to the formation of delta iron.

Silicon Additions

It was well known that a combination of silicon and chromium offered great resistance against scaling at elevated temperatures, but nickel was added to impart toughness. In general, silicon increases the hardness slightly both in the natural and in the annealed conditions; 18-8 with approximately 3% silicon is somewhat more difficult to roll than 18-8 with normal silicon content. Silicon improves the welding qualities, and when present in sufficient amount (particularly when delta iron is present) strongly inhibits the susceptibility to intergranular corrosion. It exerts only a moderate influence upon the elevated temperature properties either in short time or creep tests. In general, silicon exerts but slight influence on corrosion resistance of 18-8; each application should be based on comparative tests under working conditions.

There is an erroneous idea prevalent that silicon produces brittleness in hot rolled or annealed states. Our experience of over 15

Short Time Tests at High Temperature

Temperature of Test	Tensile Strength	Yield Strength	Proportional Limit	Elongation	Reduction
19.95% Cr, 9.12% Ni, 0.24% C, 2.25% Si, 3.70% W					
70°F.	128,000	–	64,000	41%	51%
800°F.	96,000	–	41,000	38	51
1000°F.	90,000	–	38,000	35	46
1200°F.	76,000	–	35,000	30	31
1400°F.	53,500	–	27,500	36	54
1600°F.	32,000	–	13,000	61	74
16.2% Cr, 9.13% Ni, 0.19% C, 2.6% Mo					
70°F.	97,400	45,500	35,500	66	74
800°F.	81,700	30,500	18,000	55	68
1000°F.	79,100	24,500	19,000	50	65
1200°F.	64,500	23,000	19,000	29	29
1400°F.	45,100	23,000	12,500	17	26
1600°F.	28,700	19,000	8,500	11	16

years does not warrant this belief. In fact, under certain conditions the opposite is true. For instance, a 20% chromium, 8% nickel steel containing 0.14% carbon and 3.5% silicon, in form of 0.065-in. sheet as rolled and annealed, respectively, shows 9.65 and 13.35 Erichsen test. This does not look like brittleness in either state (even though high silicon hardens 18-8 somewhat as rolled, and does not permit of such soft annealing).

Both the low and high silicon 18-8's, annealed, are subject to some lowering in impact resistance by reheating within the range 1000 to 1500° F.; the amount depends upon the composition, the annealing temperature, and the time and temperature of reheating.

As regards influence of silicon on scale resistance, three 18-8 steels with 0.40, 1.10, and 2.14% silicon were studied. After 36 hr. at 1800° F., all scale was removed and the penetration per year was estimated as 0.88 in., 0.49 in. and 0.043 in. respectively. In other words, 2.14% silicon was 22 times better than 0.40% silicon and the other steel was intermediate.

Tungsten Additions

Tungsten is usually added either to increase resistance to intergranular susceptibility or to increase the strength at elevated temperatures. The amount added may be from less than 1% up to 5%.

The first of these applications has been more popular in Europe than in this country, although Payson and others have demonstrated that it is an inhibitor of intergranular attack. At this time it is not possible to say just how much tungsten is required, for this depends not only upon the carbon, nickel, and chromium and their interrelations, but also upon the prior thermal history. This is also true of other inhibitors (including silicon, titanium, molybdenum, and vanadium).

The addition of tungsten does not improve general corrosion resistance with most chemicals nor have we found it to promote resistance to scaling at elevated temperatures. It is therefore necessary to combine silicon and tungsten, as we have done in a steel known as "Rezistal KA-2, Si, W" (to use the Krupp Nirosta system of designation). This steel has the high scale resistance of 18-8 with silicon, high strength characteristics of the tungsten addition, and resistance to intergranular attack due to both silicon and tungsten.

The very high values for proportional limit given in the accompanying table are noteworthy, and substantiate the second claim made for tungsten at the outset, as they are at least double the values usually reported for 18-8. The creep resistance is equally good. Aborn and Bain in A.S.T.M. "High Temperature Symposium," 1931, summarize available data on both short time and creep tests, and these may be studied. A word of caution is necessary: Direct comparison of data from different sources is difficult, particularly at temperatures below 1000° F. unless the prior heat treatment is stated; also the effect of carbon is much greater below 1000° F. than above 1200° F.

Molybdenum Additions

Molybdenum in amounts of from 2 to 4% is probably the most generally useful of all the additions to 18-8. It is customary to raise the chromium content to the following specification: Carbon 0.16% max., nickel 6.5 to 10.0%, chromium 18.0 to 22.0%, and molybdenum 2.0 to 4.0%.

Benefits of molybdenum are along three different lines: First, it enhances general cor-

rosion resistance against many chemicals and, so far as the writer is aware, never lowers it. (An outstanding example is in the case of sulphurous acid and sulphite liquors in the paper pulp industry.) Second, it has about the same effect as tungsten in raising the strength at elevated temperatures. Third, it is a strong inhibitor against intergranular attack when used in a properly balanced analysis; fusion welds that cannot be made with safety with 18-8 unless subsequently heat treated, may be made with the molybdenum-bearing alloy.

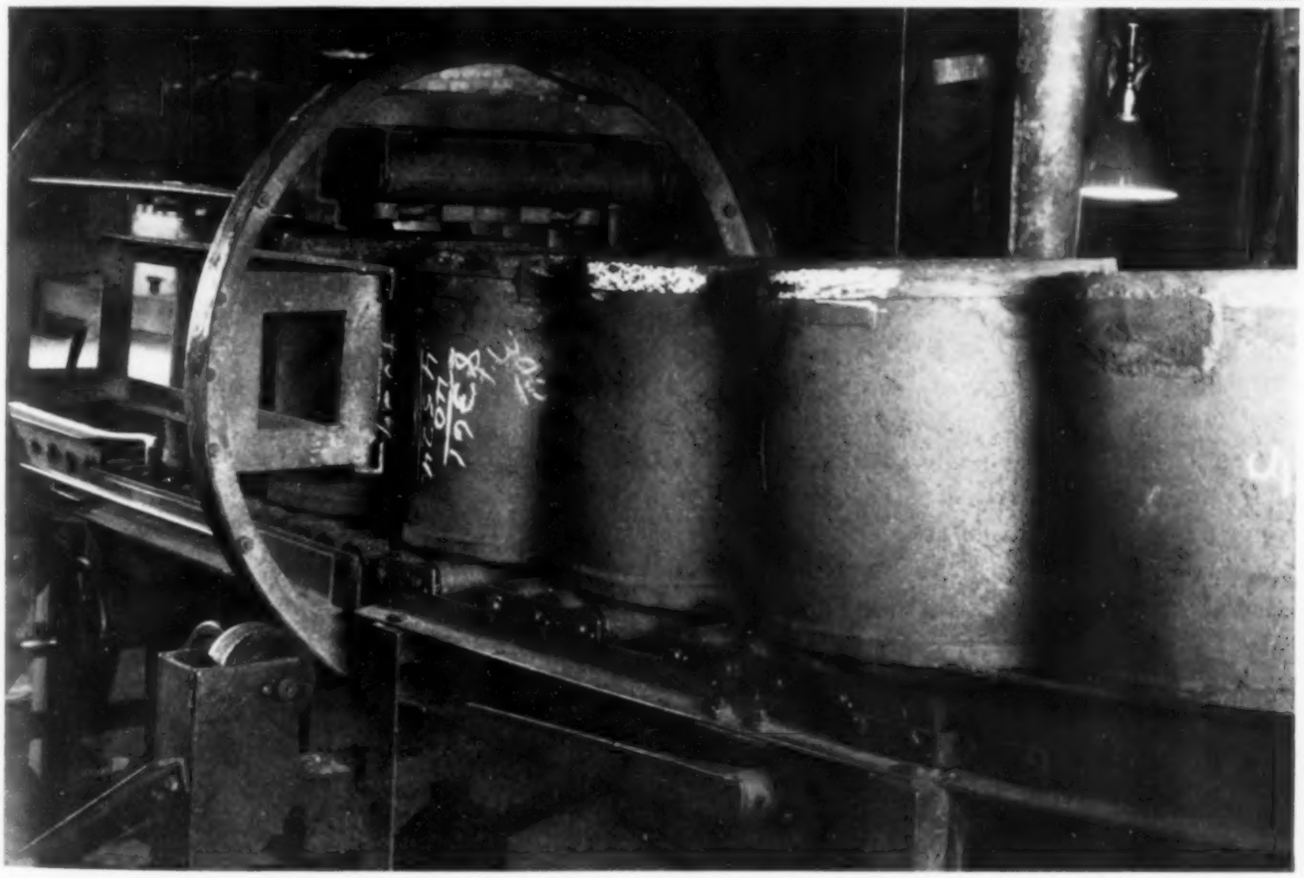
All these advantages naturally cannot be had without some increase in cost.

Data on strength at high temperature are quoted in the table from Aborn and Bain for samples soft annealed to 173 Brinell. The continuous falling off in elongation and reduction is unusual, for ordinarily a minimum is reached at from 1200 to 1400° F., followed by a sharp increase as higher temperatures are reached.

Creep values for the same steel have been sent by the Crane Co. for 1% total creep in 10,000 hr. as follows: 1250° F., 20,000 lb. per sq. in.; 1400° F., 12,500; 1500° F., 8000; and 1600° F., 4000.

Titanium and Other Additions

The modifications of 18-8 have been given in the order we have studied them and in the order the organization with which I am connected has manufactured them commercially for American consumption. The most recent employs titanium, not as a mere deoxidizer, but in substantial amounts remaining in the alloy. Thus far it seems to be for one purpose only, that is, for the prevention of intergranular corrosion. It does not serve to enhance general corrosion resistance — from some experiments



High Silicon Rezistal Has a Long and Useful Life When Made into Carburizing Containers and Covers. This photograph shows a number of these Rezistal pots and the rollover mechanism in the heat treating department of Eaton Manufacturing Co., Cleveland.

it seems even to lower it very slightly in 65% nitric acid.

In the case of titanium, as well as some other additions, there seems to be an annealing temperature that should not be exceeded. In fact, the prevention of intergranular susceptibility and the securing of maximum general corrosion resistance do not usually occur at the same annealing temperature. Newell called attention to this in *Transactions*, A.S.S.T., Vol. 19, and expressed the opinion that "it is obviously better to have a general diminishing of corrosion resistance than to have definite intergranular corrosion which could be construed as making the alloy quite unreliable under conditions of stress at either low or elevated temperatures."

Many other additions to 18-8 have been made but they have not had great commercial success. Copper has a beneficial effect in reducing corrosion from cold and dilute hydrochloric acid, ammonium chloride, and brines, but seems definitely to interfere with resistance to intergranular susceptibility — at least for additions up to 2%. The same seems true of aluminum and possibly zirconium. Double additions of molybdenum-copper, tungsten-titanium, and silicon-zirconium possibly have limited uses for some special condition. Vanadium seems to act somewhat like titanium, but a larger amount is needed.

Stability of the Structure

In the Henry Marion Howe memorial lecture, 1925, the writer presented in a general way the similarities and differences between ordinary or ferritic alloys and the austenitic alloys. At that time it seemed to be generally believed that the metallurgy of austenitic alloys such as 18-8 was delightfully simple. This was the result of a belief that the austenitic steels were perfectly stable, rather than metastable, and when long exposure to somewhat elevated temperatures began to show mysterious changes in them we had to reform our ideas as to the simplicity of "gamma-iron metallurgy."

Many students now consider 18-8 as a borderline alloy (the usual commercial range is from 16.5 to 20% chromium and 7 to 10% nickel), but that an alloy of 0.09% carbon, 26.2% chromium and 18.7% nickel is stable, that is, that it consists of one phase at all temperatures. But does that mean freedom from change by long heating to say 1200° F. for 700 hr.? Not at all. As compared to the 18-8 with molybdenum, described above (a two-phase alloy), it may be said that the single-phase alloy (26-19) was much more affected mechanically by long time reheating than the two-phase steel, while the opposite was true magnetically. The former did not change in phase relationship but the latter did. A "borderline alloy" such as 0.06% carbon, 16.6% chromium and 9.1% nickel, under the same treatment, changed both statically and in magnetic susceptibility. It hardened, gained in strength, lost in ductility, and passed from nonmagnetic state to one of quite strong magnetic susceptibility.

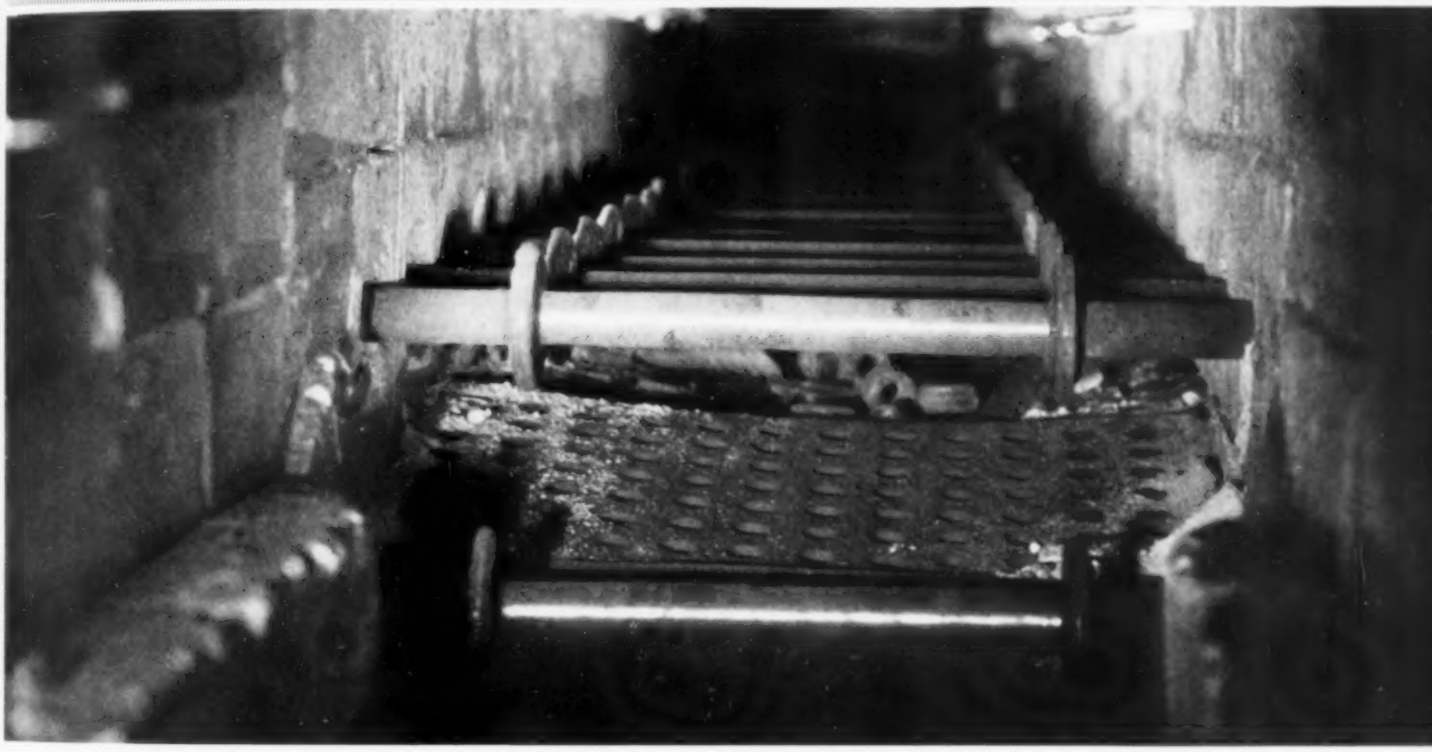
These examples illustrate the complexity of gamma-iron metallurgy, and addition elements do not make it simpler.

It is quite certain that complete solution of the various chemical elements existing in the metal in the form of austenite represents the highest degree of corrosion resistance; it is also probably true that such a condition is most susceptible to injury by certain reheatings, which heat treatments involve the incipient separation of carbides from the austenite. It has not been proven for all alloys, but possibly a condition of complete spheroidization of the carbides represents a high degree of general resistance — in fact, a commercial resistance to all but the most extreme conditions of corrosion.

A form of annealing referred to as "stabilizing" against intergranular corrosion has received the recent attention of Miller, Bain, and others (*Transactions*, A.S.S.T., June, 1933). Miller soon discovered the difficulty of stabilizing an alloy previously annealed from a very high temperature. As remarked above, the ideal is doubtless a uniformly dispersed condition of carbides in a coalesced condition. This is most readily attained when the grain size is small, either as the result of low finishing temperatures in rolling or forging or by cold work or by a combination of both. For about eight years we have been commercially annealing hot rolled material in that way, particularly when the purpose of the annealing is to improve machinability of the material.

The exact temperature for annealing each 18-8 modification has not been determined with accuracy, and the time required for stabilizing will depend largely upon the exact condition of the material under treatment. It is necessary in each case to have a properly balanced composition, and not merely some four or five elements in indiscriminate quantities.

It is necessary to emphasize that most of the experimental work has included relatively short reheating times within the dangerous zone between 1000 and 1500° F., and the results should not be considered applicable to those more or less indefinite periods of exposure in a piece of operating equipment. While the type of failure that may occur in use appears somewhat similar to the intergranular attack produced by corrosive liquids at moderate temperatures in metal previously exposed to the dangerous zone, it is not certain that the actual failure is the same. In one case it appears to be intergranular oxidation, and in the other actual solution of material between the grains, while the grains themselves are practically unaffected. 18-8 and its modifications fall off in ductility within certain temperature ranges and it is possible that fatigue cracks start between the grains and that the surfaces of the fatigue cracks become oxidized. In both cases we have intergranular failure but probably not from identical causes (excepting insofar as carbide precipitation predisposes the material in both conditions to intergranular corrosion).



Rezistal with Added Silicon Is Used for the Rollers in This Furnace for Hardening Springs. Carrier trays travel from the far end to the opening into the quench in the foreground. Courtesy of Cleveland Wire Spring Co.

Referring again to the Howe Memorial Lecture for 1925, the writer said: "Gamma-iron metallurgy is in the making. We shall know better how to use these steels when we understand their metallurgy and properties. I hope my contribution may arouse a more general interest in them and more particularly in a study of gamma-iron." The response has been most gratifying, as the voluminous literature of corrosion resistant steels attests, but the subject is not yet a closed book.

By John J. Egan, Walter Crafts, and A. B. Kinzel
Union Carbide and Carbon Research Laboratories
Long Island City, N. Y.

Toughness of Alloy Steels at Low Temperatures

IMPROVEMENTS in the handling of liquefied gases, dewaxing of oils, and refrigeration, and the use of automobiles and aircraft in temperatures as low as 60 below zero make it important to study the properties of materials at low temperatures. The literature as well as common experience indicates that the static properties of steels are not seriously altered under such conditions. The impact strength, on the other hand, is generally lowered to such an extent as to render many steels unsuitable for service. This subject has long had anxious consideration of railroad operators in states along the Canadian border. Its present interest to metallurgists is obvious.

It is the opinion of the authors that notched bar impact strength is a criterion of the ability of a metal to withstand deformation, not only in shock but in static two or three-dimensional stress as well, and it is further an indication of the resistance of the material to notch fatigue. We have accordingly chosen to study this property, which we consider one of the primary factors in determining the suitability of a steel for low temperature applications.

While low temperature impact strength is improved by a quench and draw, steels in the normalized or as-rolled condition are of greater interest to the engineer, so the present investigation has been restricted to them. Austenitic steels have high shock resistance even at very low temperatures, but their cost is too high for most applications. For this reason only the common S.A.E. steels were studied, as well as certain special analyses which were believed to possess good impact strength at low temperature. As a basis for comparison, plain carbon steels were also investigated.

All tests were made on the standard Izod machine using the 0.394-in. (1 sq.cm.) square notched specimens, the notch angle being 45° with 0.026-in. bottom radius, 0.079 in. deep, cut with a fly cutter matched frequently against a templet. The carbon and S.A.E. steels were obtained from regular tonnage production; some of the special steels were made on a commercial scale, others were small induction-furnace heats.

Specimens were immersed in a liquid cooling medium for 30 min. to 1 hr., followed by a quick transfer to the Izod vise and immediate release of the hammer (a matter of 3 to 4 sec.). Temperature loss during this interval was believed to be sufficiently slight as to be negligible, and

Abstract of Paper for Detroit Convention, A.S.S.T.

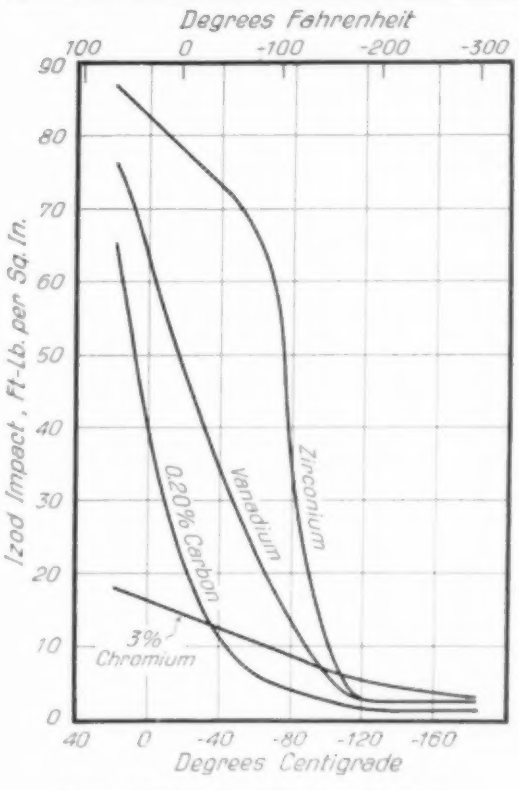
the variation in temperature loss, specimen to specimen, was naturally of a still lower order of magnitude.

The liquid used varied with the temperature desired. From 0 to —20° C. (—4° F.) ice water or iced brine was sufficient; from —20 to —80° C. (—112° F.) acetone cooled with dry ice; from this point to —150° C. (—238° F.) liquid propane cooled by means of liquid air; and liquid air at —183° C. (—297° F.). Production of temperatures from —80 to —150° C. was carried out with great care, the propane being placed in a Dewar flask, and a glass tube containing the liquid air immersed in it until the desired temperature was reached. At no time was any difficulty found in maintaining the temperature constant within plus or minus 3° C.

Discussion of Results

Typical curves (impact strength versus temperature) are plotted on this page. The general tendency is for the impact value of normalized carbon and low alloy steels to fall rapidly to a low figure at some temperature between 0° C. and —100° C. (—150° F.). Between this temperature and —183° C. (—297° F.) little additional loss occurs, the impact resistance here being in the neighborhood of only 2 to 5 ft-lb.

It would thus appear that, in general, the normalized low alloy steels should not be used at temperatures below about —100° C. for those engineering or chemical manufacturing purposes where substantial impact strength is required. Steels for use in this range must be of the austenitic type, and tests made at Battelle Memorial Institute indicate that the Charpy impact resistance of 18% chromium, 8% nickel alloy at room temperature is 80 ft-lb. and this is unchanged as low as —80° C. (—112° F.). Fortunately, however, temperatures lower than —100° C. are not usually encountered, so that normalized pearlitic alloy steels are well adapted to most demands. Tests on these steels have therefore been made with special reference to temperatures from —50 to 80° C. (—60 to —110° F.).



Impact Strength of Various Normalized Steels at Low Temperatures

In addition to the poor impact values shown by carbon steel and some alloy steels, a further disturbing factor was their erratic behavior. For example, the results of tests on chromium-nickel steels varied from 7 to 25 ft-lb. at —50° C. At —80° C. an S.A.E. 6120 steel gave 5.5 ft-lb., whereas an S.A.E. 6150 steel had an impact strength of 14 ft-lb. However, some of the steels, notably the zirconium series, were found to have relatively higher and more consistent impact strength at the low temperatures.

Although certain alloy additions improved the impact resistance and reduced the inconsistencies, steels having a tensile strength of less than about 80,000 lb. per sq.in. had substantially less variation than those steels with higher strength. This condition may be compared with the similar lack of impact strength found in the usual normalized steels at normal atmospheric temperatures when a strength of 100,000 to 125,000 lb. per sq.in. is exceeded. It would therefore appear to be necessary to heat treat steels to obtain high tensile and impact strengths, but high shock resistance is frequently not a primary requirement and normalized high strength steel should then be quite satisfactory.

For example, the average rail steel has 185,000 lb. per sq.in. tensile

strength and an impact resistance of only 2 ft-lb. at room temperature, yet it has given good service except at very low temperatures. A 3% chromium steel in the air-cooled condition with 12 ft-lb. at −50° C. should therefore be entirely safe for rail steel even though its strength is also 180,000 lb. per sq.in. (above the limit mentioned in the preceding paragraph).

The properties of many of the normalized low alloy steels were such as to render them quite satisfactory where a higher order of impact resistance would be required. This was not true of the plain carbon steels. Some alloys added little to the shock resistance of the carbon steels, while others appeared to be effective only when two or more alloys were combined. The influence of zirconium and vanadium was found to increase in proportion to the alloy content, effective improvement being obtained at 0.50% to 1.00%. In the case of the other alloys, chromium, molybdenum, nickel, copper, and manganese, no direct relation appeared to exist between alloy content and improvement.

Combinations of alloys produced rather surprising results. Zirconium steel was influenced only slightly by manganese and copper; it was harmed by nickel and improved by molybdenum. Vanadium steel was deleteriously affected by manganese and nickel and helped by chromium. Although nickel alone improved the normalized steel much less than might be expected from the reported results of heat treated specimens, additions of other alloys to nickel steel conferred a decided benefit. Chromium steel was improved by additions of vanadium, nickel, copper, and manganese. The addition of zirconium and nickel improved molybdenum steels, while manganese had little effect.

In classifying these results it was noted, in general, that the deoxidizing alloys, such as zirconium and vanadium, combined with the carbide-forming alloys chromium and molybdenum, gave good results, but that poor or doubtful results followed the combination of the austenite-forming nickel, copper, and manganese with the deoxidizing alloys zirconium and vanadium. Similarly, the carbide-forming alloys gave good results in combination with austenite-forming alloys.

Although in general the low alloy normalized steels under the best conditions do not appear to be suitable for use in engineering applications below −100° C. (−150° F.), many of them have sufficiently good impact resistance to make them suitable at −80° C. (−110° F.).

If a limiting impact strength of 10 ft-lb. be considered adequate, several steels in addition to those appearing in the adjoining table would be acceptable. (The table itself is much abridged from the available data.) Nickel-vanadium, nickel-copper, "cromansil," chromium-copper, zirconium, and vanadium would be satisfactory.

If we now consider the properties at −50° C. (−60° F.), which we have taken to be the limiting low temperature for service under atmospheric conditions, a slightly different listing ensues. All the steels listed at −80° C. are, of course, also satisfactory. In addition, 3% chromium, chromium-vanadium, nickel-molybdenum, and plain molybdenum steels might be included. Carbon steels are, in general, not satisfactory below −15° C. (+5° F.), where good resistance to impact is necessary, and may well be unsuitable at temperatures in the vicinity of 0° C. (+32° F.).

Izod Impact Strength, Normalized Steel at Low Temperatures

Metal	Izod Impact Strength Ft-Lb. per Sq. Cm			
	Room	-50°C. (-58°F.)	-80°C. (-112°F.)	-183°C. (-297°F.)
Armco iron	64	9	3	
SAE 1020 (0.20% carbon)	65	7	2	
SAE 1030 (0.30% carbon)	49	9	5	
Rail steel (0.80% carbon)	2.5	2.0		
SAE 2335 (3% nickel)	15 to 21	6 to 8	5.5	2.0
SAE 3135 (Nickel-chromium)	15 to 41	7 to 25	4 to 17	3
SAE 6125 (Chromium-vanadium)	21 to 89	6 to 16	5 to 11	2
3% Cr, 0.25% C	18	12	9	3.5
"Cromansil" (0.5% Cr, 0.5% Si, 1.5% Mn, 0.10% C)	48	11	10	3.5
Zirconium (0.07% C, 0.20% Zr)	70	78	11	2.3
(0.16% C, 0.66% Zr)	87	71	34	2.5
Vanadium (0.15% C, 0.46% V)	76	29	14	3.0
Copper-chromium (0.10% C, 0.83% Cr, 0.53% Cu)	85	92	41	2.5

By Wirt S. Scott, Special Representative,
Westinghouse Electric & Mfg. Co., Mansfield, Ohio

HEAT TREATMENT OF ALUMINUM CASTINGS

ALUMINUM alloy castings with high tensile strength and elongation, made continuously and uniformly on a production basis, necessitate not only first class foundry practice, but close temperature control in subsequent heat treatment, together with uniform heat distribution throughout the charge. These two items are distinct. "Temperature control" is done by automatic devices actuated by a pyrometer measuring temperature at one point in the furnace; "heat distribution" is the relation of the temperature at any part of the charge to that point controlled by the thermocouple.

Metallurgists usually have facilities for making accurate investigations for determining the proper heat treatment procedure to obtain certain physical properties, since, in a laboratory furnace, the equipment is of relatively small dimensions and the test specimen may be located very close to the temperature controlling thermocouple. However, the shop may or may not have equipment capable of duplicating such test results. A manufacturer may therefore be penalizing himself by using equipment in the heat treating department which is incapable of producing physical results attainable in the laboratory. In any event, these facts should be definitely determined.

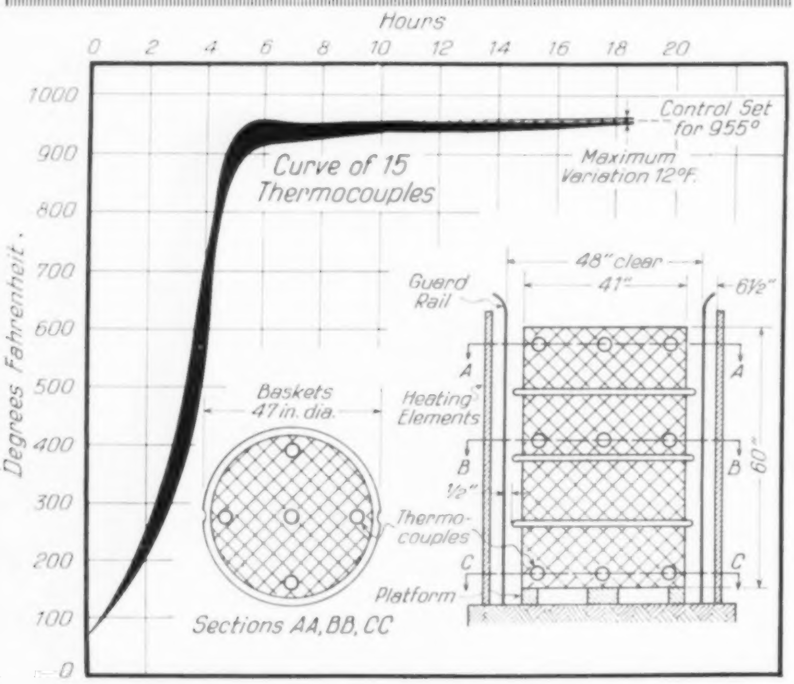
It may be found, for instance, that the product requires heat treatment at some definite temperature, with an allowable variation of not more than 8° F. plus or minus. If, under production conditions, the variation is 25° plus or minus from the desired temperature, then it is an indisputable fact that either the number of rejects is very great or the tolerances for acceptance tests must have been set wide enough to permit materials having reduced physical properties to pass inspection.

Such a condition is not the fault of the metallurgist or the metal. The responsibility rests entirely with the management. Seldom would a metallurgist care to set up shop specifications so strict that a large percentage of the product would be rejected. He has to make the best out of the heat treating equipment. Nevertheless, he has certain responsibilities which are his duty to exercise. These may be enumerated as follows:

1. Determine the correct heat treating temperature for the particular metal in production and the maximum temperature variation from normal which will produce the physical properties desired.

2. Explore, with thermocouples, the charge in the shop furnace, and find just what percentage of the material is now being heat treated at the proper temperature.

3. Determine the manner in which the shop, the sales department, and the user are being penalized by a non-uniform product.



Sketch Showing Location of 15 Thermocouples in Fully Loaded Furnace and Overlapping Curves Drawn by the Recorders. Acceptable tolerance was plus or minus 10° F.; maximum variation measured at end of heat was plus or minus 6° F.

Evaluate this penalty in dollars and cents.

4. Determine if there is a furnace on the market that will produce exactly the results required; find out what interest it will pay on the total investment, taking into consideration all factors entering into costs.

5. In purchasing a furnace, specify that temperatures must be thoroughly explored throughout the charge under operating conditions, and that the maximum variation in a representative load be not more than a prescribed number of degrees, plus or minus, from a given temperature. The uniformity of heat distribution must be such as will give the metallurgical result required.

That such demands are not academic and impracticable may be proven by citing experience in the heat treating department of a large user of aluminum castings. In this particular plant under discussion, three alloys were in general use, as follows: (*a*) 92% Al, 8% Cu, for general use; (*b*) 95% Al, 5% Cu, for high strength requirements; and (*c*) 95% Al, 5% Si, for pressure work.

It is the purpose of this article to describe the results secured in the heat treatment of the second alloy for producing maximum tensile strength and elongation.

It is well known that the strengthening and hardening of aluminum alloys by heat treatment is due to constituents which are more soluble in solid aluminum at high temperatures than at low temperatures. The "solution heat treatment," therefore, consists in heating the alloy to a temperature selected to put as much as possible into solid solution, and then quenching to retain this condition temporarily (or, rather, to control the manner of its precipitation). The fact that the quenching temperature happens to be near the softening point of the constituent itself is only incidental, but it does increase the need for uniform heat distribution throughout the entire charge, with close temperature control, if the high side and "burning," and the low temperatures preventing substantial solution, are to be avoided.

In the plant in question a completely muffled type fuel furnace has been used for this work. It had a long nickel-chromium muffle, 24x24x72 in., heated externally by four gas burners. There were four thermocouples inserted into wells within the muffle. Attendants were on duty, 24 hr. per day, to adjust the burners and maintain the temperature recorded by one of these pyrometers at 510° C. (950° F.). The hot junction for this pyrometer was located approximately at the center of the muffle. The castings were all small, weighing from 0.17 to 4.77 lb., with an average of 0.7 lb.

Two or three test bars were placed in each charge and their physical properties determined after the treatment. The results were so variable that it was practically impossible to reject all castings not coming up to the requirements in tensile strength and elongation. Frequently, elongations as low as 4% and tensile strengths as low as 22,000 lb. per sq.in. were encountered, which may be compared to figures for this alloy given by Edwards, Frary, and Jeffries on page 201, "The Aluminum Industry," of 28,000 to 38,000 lb. per sq.in. tensile strength and 6 to 12% elongation in 2 in.

In an effort to secure better results, a decision was made to install a pit type electric furnace. Incidentally, it was to have a capacity of 1500 lb. per charge and dimensions 48 in. diameter by 60 in. deep. Baskets for holding the castings were to be made of heavy wire netting in two different types — a large basket

for taking the entire charge, and small baskets of the same diameter as the large basket, but only one-half or one-fourth as deep. Specifications put into effect were as follows:

Heating — Heat the castings for a minimum of 12 hr. at a temperature between 941 and 959° F. (505 to 515° C.). This may require a total time of 18 to 24 hr. depending upon whether the furnace is hot or cold at the beginning of the heat.

Quenching — Remove from the furnace, and quench immediately in water.

Straightening — Castings that warp during the heating or quenching operations are to be straightened immediately after quenching in the department where the heat treating is done.

Aging — Since age hardening at ordinary temperatures is practically developed in 48 hr., this interval shall be permitted before machining and assembly of the castings.

Testing — Test bars treated according to this treatment shall have the following *minimum* properties: Ultimate tensile strength, 29,000 lb. per sq.in.; elongation in 2 in., 6%.

The pit type electric furnace installed for this job has an electrical capacity of 75 kw. at 220 volts. A motor-driven fan is installed directly under the cover so as to circulate the air and assist in distributing the heat. Much to everyone's surprise, repeated tests on this furnace under full charge disclosed the fact that correct heat distribution existed without operating the fan.

A number of tests were made during operation using 15 thermocouples placed directly within the charge, as shown in the diagram. This gave information as to heat distribution at three sections — top, middle, and bottom. The maximum variation found at the end of the soaking period for the entire charge was plus or minus 6° F. from the intended operating temperature.

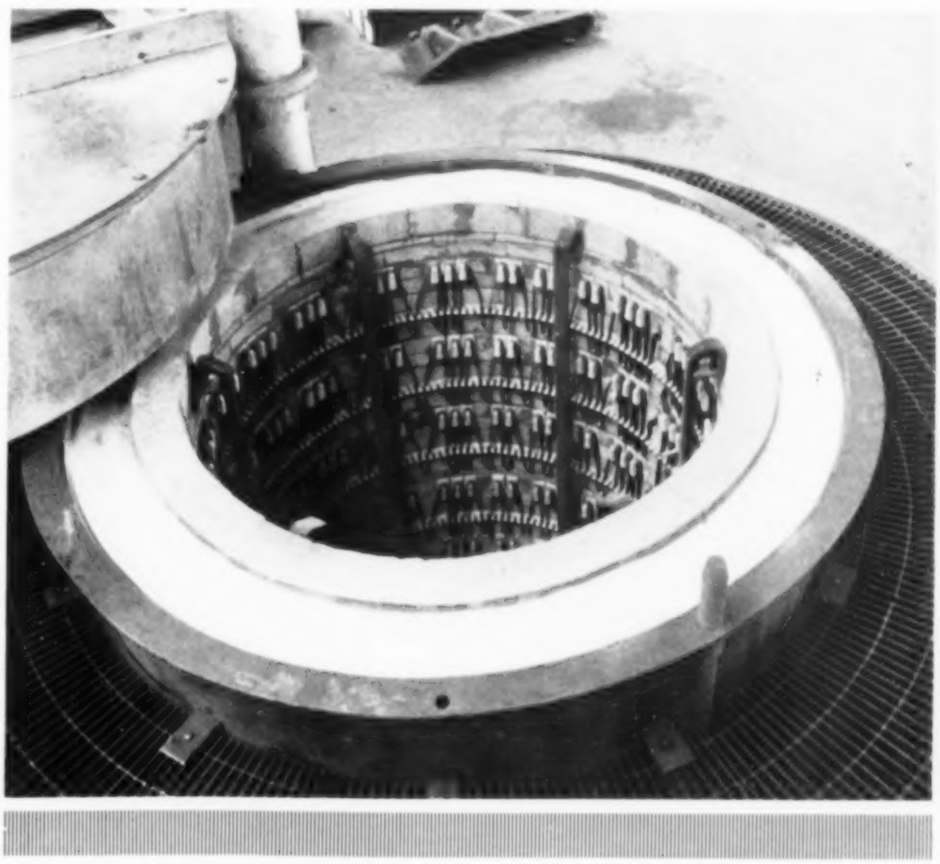
This uniformity of heat treatment has promoted uniformity in the heat treated castings. A report from the metallurgical department states that the tensile strength of the 95% Al, 5% Cu alloy now averages from 30,000 to 35,000 lb. per sq.in., and that the elongation varies from 8 to 12%. The average is 32,000 lb. tensile and 10% elongation.

A description of the furnace will be of interest. (That this performance was not a matter of chance or accident, it may be noted that a larger furnace of the same general type was installed in another department for normalizing, hardening, and tempering of alloy steel bolts at temperatures of 1650° F., 1450° F. and 925° F. respectively, with equally good heat distribution throughout the charge.)

One view shows the furnace for aluminum alloys with the cover swung to one side, ready to receive a charge. The furnace is installed in a pit, and extends above the floor level a convenient height for charging by overhead crane. Heating elements near the top may be seen, also the nickel-chromium guard rails which act as guides for the baskets containing the charge. Heating elements of the ribbon type are mounted on special refractories with spacers underneath; these ribbons are definitely located in the detailed drawings made when designing the furnace. With a proper heat distribution attained, it is evident that this same heat distribution will result for successive heats.

A general view shows the furnace under

Empty Furnace, Cover at One Side, Showing Resistors, Refractory Supports, and Alloy Guard Rails



heat, with the cover in place. The quench tank is shown in the foreground, and in the rear, between the quench tank and furnace, may be seen one of the large wire baskets used for holding a complete charge. Control equipment is at the left. Magnetic contactors or control panels are placed at each end of the panelboard, mounted in enclosed steel cabinets. Next to each control panel is an indicating and controlling pyrometer for that circuit. A separate two-point recording pyrometer is mounted on one of the lower panels, for recording the temperature of each of the control zones.

The motor for driving the fan inside the furnace may be seen mounted directly on top the cover, while the motor for raising this cover is mounted on the arm near the mast.

The cover is raised vertically by means of a small jib crane and motor, and is swung to one side by hand. Limit switches, on the mast, automatically stop the motor the instant the cover is lowered in place and seated in the sand seal around the top of the furnace, or, when opening, after the cover has cleared the centering pin.

This furnace has shown a variation in heat distribution of not more than plus or minus 8° F. throughout the charge since it was first put into service two years ago. It appears to have a definite heat distribution characteristic which will remain unchanged for the life of the furnace, an estimated period of 15 years with an operating temperature under 1000° F.

An actual comparison of gas and electric power cost was not available, due to the fact that the gas furnace was designed for a production of 500 lb., while the electric furnace has a capacity of 1500 lb. However, making due allowance for difference in furnace sizes, and on the basis of 30¢ natural gas and 1¢ electric power, the operating cost would be equal. This is due, largely, to the greater efficiency of a pit type furnace over a horizontal muffled type. The radiation losses of the furnace when operating at 955° F. are 7.5 kw. per hr., under saturated conditions. Not one cent has been spent for maintenance.

Aside from the ability to produce castings of definite physical properties, the management has found it to be of advantage to substitute aluminum alloy for many brass castings, at a saving in metal cost, according to the last analysis, of $8400 a year. This is only one of the instances where collateral advantages of great importance follow the adoption of modern practices in auxiliary departments.

Complete Installation Includes Electrical Control, Work Baskets and Quench Tank

By O. W. McMullan, Timken-Detroit Axle Co., Detroit Mich.

CONTROLLED COOLING TO PROMOTE MACHINABILITY

SOME months ago a certain manufacturer of automotive gears ran into serious machining trouble. The offending metal was a heat of S.A.E. 4615 open-hearth steel. It had the following analysis: Carbon 0.17%, manganese 0.45%, phosphorus 0.015%, sulphur 0.030%, silicon 0.26%, nickel 1.76%, and molybdenum 0.27% (well within specification). The gear blanks had been normalized in a pusher furnace.

After some of the offending blanks had been returned to the steel manufacturer, they were retreated by holding 3 hr. at 1800° F., cooling to 1200° F. in 6 hr., and then in air. The first piece of this material ruined the cutter, although the Brinell hardness was only 156.

Microscopic examination at 500 diameters revealed a number of structureless grains, which on re-etching in nital developed faint needle-like structure typical of martensite in a background of austenite. Some of the areas were isolated, but most of them were parts of pearlite grains — some at boundaries and others enclosed within the pearlite. (Pearlite in steel of this analysis is granular rather than lamellar.) The first photograph shows a microcharacter scratch across a mixed grain and proves the area with martensitic markings to be much harder than the ferrite and also harder than the pearlitic portion of the same grain. It was thought that these very small but very hard particles had an influence on the poor machining qualities of the steel, and we became interested in clearing up the point, although neither the gear company nor the steel company was connected with our own either as producer or consumer.

Presence of such hard particles cannot be detected by the Brinell test, since they are merely pushed into the softer ferritic matrix. The action might be compared to the Brinelling of gray cast iron containing excess carbide particles. There, also, the Brinell hardness may not be a guide for machinability.

Since only a few pieces of this first steel were available, the relationship between structure and machinability (that is, tool life and smoothness of finish) was studied on two other heats of S.A.E. 4615. They were of higher manganese content (0.65 to 0.69% instead of 0.45%), made in an electric furnace by another steel company. Two heats were selected because of a known difference in their machining qualities. The one classed as "poor" had 0.21% carbon; the "good" one 0.15%. The McQuaid-Ehn test showed the usual "moly" type of structure, grain size mostly No. 8 in both, with a little more variation in the good cutting steel. The latter also showed banding in both the case and the core.

Abstract of paper for A.S.S.T. Convention, 1933

Cooling Experiments After Holding 2 Hr. at 1800°F.

Treatment No.	Cooling Schedule				Brinell Hardness		Microstructure of Machinable Steel
	Medium	To Temperature °F.	Holding Time Minutes	Final Cooling in	Good Cutting Steel	Poor Cutting Steel	
2	Furnace	1600°		Air	174	207	Some partially martensitic grains
3	Furnace	1400°		Air	183	217	Same; coarsened, banded ferrite
5	Furnace	1200°		Air	192	202	Still coarser, more martensite
7	Furnace	1000°		Air	163	212	Same as No. 5
9	Furnace	800°		Air	146	156	Same banding as No. 7; no martensite; pearlite partially spheroidized
11	Furnace at 1200°		15	Air	166	187	Martensitic grains; banding somewhat suppressed
12	Furnace at 1200°		75	Air	187	202	As No. 11, but banding and martensite more pronounced
13	Furnace at 1200°		75	Water		235	Grains of ferrite and martensite (no pearlite)
14	Lead at 1200°		3	Water	217		Same as No. 13.
15	Lead at 1200°		60	Water	163		Not banded; some pearlite appearing
16	Lead at 1200°		3	Air	170		More pearlite than No. 15; some martensite grains
17	Lead at 1200°		60	Air	156		More pearlite than No. 16
20	Furnace at 800°		15	Air	163	192	Some small grains of martensite; slight banding
21	Furnace at 800°		75	Air	163	187	No banding, no martensite
22	Furnace at 800°		75	Water	170	209	Same as No. 20

The normalizing treatments given these two heats were not identical, as will be explained later. Various cooling cycles were therefore given to samples cut from machined parts to determine if the difference was in the steel or in the treatment. Schedule of treatments with resulting Brinell hardness is given in the table. The apparent irregularity in treatments 1 to 10 is probably due to the fact that the limited number of samples tested failed to give a representative average.

A difference was found between the two heats of steel, but it was a difference in degree rather than an entire difference in action. The steel difficult to machine was harder through all the range of treatments, probably due to higher carbon content. It showed greater air hardening with less ferrite separation when cooled from above the critical range and more martensite when cooled in air from within the critical range. Slow cooling to a slightly lower temperature also was required to eliminate all of the martensite.

It was concluded that the difficulty in machining was probably largely due to the difference in treatment rather than inherent difference in the steel.

Notes on microstructure of the easily machinable steel are given in the table. As the critical range is entered in treatments 1 to 10, ferrite separation and banding occur, with local increase in carbon concentration and the formation of more and larger martensitic grains. By cooling in the furnace to 800° F. (that is, below Ar_1), martensite is no longer formed and little difference in structure results below this temperature, even when furnace cooled to room.

Development of Bands

Banding develops during slow cooling in steel which has the tendency to do so, and in an attempt to eliminate banding by faster cooling (and perhaps some of the martensite also because of more even carbon distribution) other samples were transferred from 1800° F. to a furnace set at 1200° F. These samples in treatments No. 11 to 13 did show less banding, but also showed considerable ferrite separation and martensitic formation. The unexpected result was the formation of much more martensite in No. 12 and 13 when held for the longer time at 1200° F. The grain is also somewhat coarser. (See the second micro.) Since there is little or no pearlite in steel quenched from 1200° F. (treatment 13), that pearlite which was found after treatments 11 and 12 must have formed during the air cooling.

Still more rapid cooling from 1800 to 1200° F. was obtained by quenching the samples in

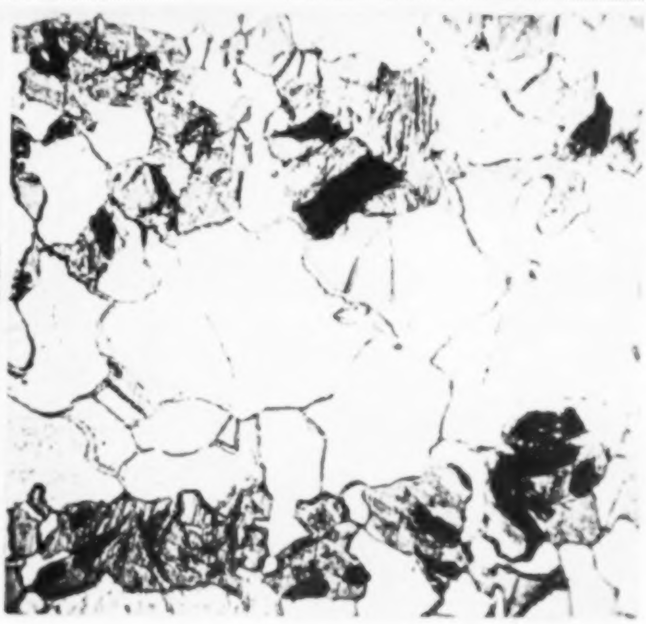
molten lead at 1200° F. and further cooling as described in treatments 14 to 19 inclusive. The lack of pearlite after treatment 14 may have resulted from too short a time at 1200° F. before quenching. Even this more rapid cooling rate allows considerable ferrite separation, which is probably necessary to easy machining (in turn due to the coarsening of the structure produced thereby). On the other hand, too slow cooling will produce banding and separation of ferrite into large areas, which are believed to give poor finish.

The results here obtained show banding to take place during slow cooling in the upper part of the critical range; if one attempts to avoid this by a more rapid rate of cooling through the lower part of the critical range, martensitic crystals will be produced, detrimental to tool life and finish.

Treatments 20 to 22 were devised to eliminate banding and martensite by striking a happy medium in the cooling rate. By transferring the samples from a furnace at 1800 to one at 800° F., the rate of cooling would automatically become slower as 800 was approached. The third micro shows the uniformity of the structures obtained by treatment No. 21. A furnace at 800° is apparently a little too high if the samples are not held long enough at this temperature or if they are water quenched (treatment 20 or 22). This is especially true of the heat of steel that machined poorly.

It is believed that this structure (treatment 21) will approach the ease of machinability and cutter life obtained with furnace cooled material, but will still retain sufficient uniformity of structure to give a good finish. This was checked on production parts by a similar treatment, except that the lower furnace was at about 600° F. The heat from several hundred pounds of metal raised its temperature to about 1050° F., but this dropped back 200° in a short time, and then more slowly until below 800° F. The parts so treated were taken from a lot giving trouble, since only 8 or 10 pieces were produced per cutter grind. After the stated treatment, the entire lot of 100 pieces was machined without grinding the cutter and a much better finish obtained. Repeated checks have given similar results.

Nickel-Molybdenum Steel, Practically Unmachinable, Had Martensitic Grains in Ferrite Matrix. Note the narrow microcharacter cut across the hard particle. 2000 X



Banded Structure in Machinable Nickel-Molybdenum Steel After Treatment No. 12. Stay at 1200° has favored banding and partial decomposition of austenitic areas into martensite. 1000 X

Photomicrographs for This Paper by Roy Roush, Cadillac Motor Car Co.

The usual commercial practice in normalizing this type of alloy steel is either to heat the parts in a batch type furnace at 1650 to 1800° F. and pull out into air, or else to run them through a continuous furnace whose maximum temperature is the same as in the batch type and with a temperature of 1200 to 1000° F. (or at least above Ar_1) at the discharge end.

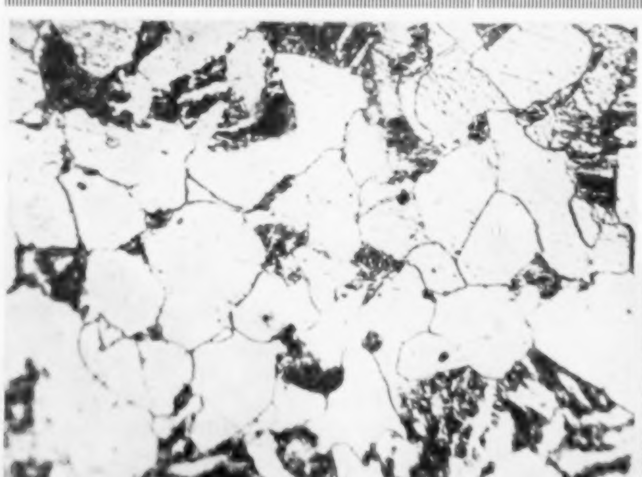
Normalizing at high temperature is to develop coarse-grained pearlite which is usually considered to be the most desirable structure for machining. Furnace cooling gives this structure, but consumes too much furnace time and adds to the cost. Air cooling from 1800 produces a uniform and finer grained structure, relatively free from banding, and gives a good finish in machining, but tool life and ease of machinability are better with softer structures.

For heats of steel subject to such formations as we have been investigating, the continuous cycle promotes banding by slow cooling in the furnace at high temperatures; then the more rapid cooling through Ar_1 forms martensite. The steel designated as "poor machining" had been put through a continuous counterflow furnace, electrically heated, and discharged at about 1000° F. Cooling in the lower critical range was accelerated by the cold blanks entering in the adjacent row. The "good machining" steel, on the other hand, had been normalized in an oil-fired, straight through, pusher furnace whose discharge end temperature was approximately 800° F.

The work from the counterflow furnace was banded and contained considerable martensite in some of the pearlite bands, while other bands were nearly free from that constituent. The work from the straight-through furnace contained no martensite. When a sample of the poor machining steel was normalized in the straight-through furnace, it contained but few hard grains.

As the poor machining parts had all been semi-machined before reaching the finish machining operation, they could not be re-run through the high temperature cycle. In place of this they were given a draw at 1200° F. for 2 hr. The Brinell hardness was only slightly reduced, but the cutter life increased from three or four pieces per grind, all of rather poor finish, to 35 or 40 pieces per grind, and at the same time the surface finish was greatly improved. The expected tempered structure was produced in the former martensitic grains.

A few tests on different types of steel show that martensite does not always form after normalizing. The number of tests was not sufficient to say definitely that one type of steel was more susceptible than others, but martensitic grains could be produced in all the nickel-molybdenum steel tested. Some steels with greater hardening power when water or oil quenched from above the critical range did not produce martensite on air cooling, while others with less hardening power contained much martensite after air cooling. Further investigation is needed to determine the cause of this undesirable structure.



Fast Cooling Through Upper Critical Prevents Banding and Slow Cooling Through Lower Critical Prevents Martensite. Treatment No. 21. 1000 X

Chrome-Vanadium Steel (S.A.E. 6115) Cooled in Furnace to 1200 F. and Then in Air. No martensite is found. Grain size No. 8. 1000 X

EDITORIALS

A New Name for the A. S. S. T.

ONE action taken unanimously by the Board of Directors of the A.S.S.T. at their meeting last month will doubtless cause much interest. That was a resolution on the perennial question, "How about the name of the Society?"

It will be remembered that the present Society was formed by the amalgamation of two competitive groups, the Steel Treating Research Society, centering in Detroit, and the American Steel Treaters' Society, centering in Chicago. The name then adopted — American Society for Steel Treating — was something of a compromise, aimed to satisfy both of the old organizations, but more than that it fairly well represented the aims and activities of the consolidation.

For some years the principal energies of the rapidly growing young Society were to disseminate information about the heat treatment of tool steels and alloy steel. Doubtless the widest interest was in tools and furnaces, for every metal-working plant used and heat treated tools in a rule-of-thumb manner, but industry generally was waking up to the advantages of the strong, tough alloy steels, and there seemed to be an insatiable demand for information about them, which the Society filled by numberless chapter meetings and the voluminous *Transactions*. Success in its ideal of service was undoubtedly the reason for the rapid growth of the A.S.S.T. in membership and resources.

As we look back, it seems perfectly logical that the interest of the members should gradually widen out from fine steels to fine metals generally. Strong and forward-looking producing companies were vigorously promoting the non-ferrous metals; important advances were taking place in their alloying, manufacture, and treatment, and they became strong competitors of the steels in many fabrications. Questions regarding the economic utility of these new alloys naturally arose in the minds of the members, and this was quickly reflected in the chapter and convention programs, where an increasing amount of time was devoted to subjects far afield from "steel treating." Perhaps an analysis of the 1933 edition of the National Metals Handbook indicates the present situation. It has about 1,000 pages of data on iron and steels, and 500 pages on aluminum, copper, nickel, and other non-ferrous metals and alloys. Of the 1,000 pages on ferrous metals, only 125 have to do with recommended practices for heat treatment.

Obviously, therefore, the name of the So-

ciety has been outgrown. This has been recognized by prior Boards of Directors, but despite much discussion, none of them could convince itself that the "going" value of the old name should be discarded. It has become more and more apparent, however, that the change will have to be made sometime, else increasing numbers of men who are interested in manufacture and use of fine metals will remain outside the Society simply because they do no heat treating of steel. No matter how often the present scope of the Society may be explained, the name persists in defining it as a narrow specialty.

The new name approved by the Board of Directors, subject to a vote changing the Constitution, does remove this limitation. "American Metals Society" uses two words of the old name, hence will not sound too harsh to members of long standing. It parallels the name of other important Society activities — Metal Congress, National Metal Exposition, National Metals Handbook, METAL PROGRESS. Altogether it would appear to be an important move in the right direction, worthy of vigorous support.

use metal « » use metal

Is Your Data on File?

AT LAST the cycle of employment has started upward, judged by the fact that inquiries for help are reaching the national office — the first in months. It would be well, therefore, for any member who is looking for work to make sure that he has on file a complete and clear record of his experience, the kind of work he is anxious to secure, and the expected salary.

Generally, vacancies as they arise will be filled by employing a resident of that locality, personally known to the employer. Here the chapters can do important work by organizing an energetic committee to survey the local industries and bring forward promising candidates for every opening, actual or potential. In the event that help from outside is needed, it is to be hoped that inquiries addressed to the national office of the A.S.S.T. will be quite clear as to the requirements. Only in that way can disappointment be avoided — disappointment to both sides. Lacking definite information about the job, the tendency would be to recommend the best and most versatile man on record, yet only too frequently the actual need would be for a junior analyst or pyrometer man!

use metal « » use metal

Certification of Welders and Weldings

EVER since fusion welding first was applied to important structures or equipment, where a failure might endanger life or cause serious monetary loss, the problem of making sure that the welded joint is sound and reliable has loomed large. Naturally, the owner or his insurance company has been most anxious for proof positive; the fabricator, being more familiar with the welding operation, is generally confident that results will be satisfactory in service.

Much earnest work has been done to harmonize the divergent points of view of owner and of welder. The first wants to be shown that a good looking joint is really sound underneath. The second thinks that welded joints can be accepted as trustworthy just as reinforced concrete is accepted: If the contractor is reliable, if he uses none but sound materials meeting specifications, if the work is done by competent men under independent inspection, if the equipment is adequate, and if the final structure passes a proof test — then there should be no question about satisfactory service. All the above "ifs" are readily verified by routine inspection.

"This matter of procedure control is right and proper, BUT — " rejoins the skeptical purchaser, or his engineer, architect, or insurance adjuster, "we have a considerable body of experience with reinforced concrete. Fusion welding is still so young that a parallel cannot be drawn between the two. We must have the work done by certified welders, by an acceptable process, and be shown X-ray photographs of all joints."

Shorn of its many side issues, the above represents the essential differences between manufacturers who want to sell on acceptance tests, and purchasers who insist that the process must also be subject to continual inspection and approved. Conflicts of this sort are by no means

confined to the welding industry, but were exhibited in sharp relief during the establishment of a code for welded pressure vessels and boilers.

"Qualifying the welder" has been one of the knottiest points. The aim, of course, is to insure that only skilled, reliable, and conscientious workmen be used on important jobs. Who is to certify as to these things? What tests can be imposed to measure skill? Does a small test piece represent the condition of a long joint? How can you be sure that a workman who passes a test on Friday will do good work after the week-end holiday? (Installation of "automatic" machinery only pushes the problem a little further off, for someone has to adjust the machine and watch its operation.)

When all these questions are satisfactorily answered, next comes the problem of certification. Should certificates of skill be good only for a definite shop, a definite process, and a definite class of work? How can you make them non-transferable? How can you keep clear of the politicians and other racketeers, who establish licenses primarily for taxation and to provide soft jobs for their henchmen?

Extended studies, such as the investigation of welds in structural steel by the American Bureau of Welding, have answered most of the questions about how to test welders, and the consistency of their performance. These requirements have found their way into codes or specifications covering important welded work, and the testing of welders has generally been done by casualty companies who later insure the completed installation (and who are not particularly well organized to do this work), or by inspectors in the employ of the purchaser. Sometimes this involves duplication of work, for two jobs may be in a shop at about the same time, and each inspector require his own certification, even though one crew of workmen would do all the work.

It can therefore be taken as a distinct forward step when one of the well-known and conservative testing and inspecting organizations has been able to institute a "National Weld Testing Bureau." In addition to routine inspection during manufacture and erection of a welded structure (in line with corresponding services rendered 50 years or more) the testing laboratory will, after proper investigation, certify the fabricating shop as competent to perform Class A welding.

One such certificate from an independent agency should therefore be suitable for all customers, at least for a limited time. It is understood that the individual welder is not to be "licensed," but that after passing the necessary tests, a document bearing his photograph is issued by the testing laboratory to his employer, certifying that his performance on definite classes of work, using definite tools and equipment, is thus and so. Presumably this certificate expires in the time set for a re-check of his ability, and certainly is non-transferable, either as to workman or as to shop.

Naturally such certification cannot nullify other code requirements as to fabrication, inspection, and proof test. It should, however, have an important favorable influence upon the mental attitude of many potential consumers of important welded products and writers of municipal building codes, and lead promptly toward wider acceptance of this modern method of manufacture, fabrication and erection.

use metal « » use metal

A New Slogan

NOW that the Government is depending so much — and apparently successfully — upon the psychological effect of symbols and slogans ("NRA" and "We Do Our Part"), steel treaters can follow suit with a slogan of their own. USE METAL is not a bad one — brief, to the point, and representative of their principal aims. USE METAL is constantly being argued with many who are now using concrete or wood or ceramics or fabric or synthetic chemical substances.

Sharp competition, industry vs. industry, among such competing materials is bound to become keener. What better, then, than that the chief proponents of fine metal start right at home, and bear constantly in their own minds the thought USE METAL. The more metal that's used, the more business their firm will have, the more employment for fellow members, and the more important their own position will become.

use metal « use metal » use metal

By A. L. Marshall and Maynard C. Agens
Research Laboratory, General Electric Co.

BRIGHT ANNEALING IN MIXED GAS

IN the annealing of polished low carbon steel where it is necessary to preserve the original finish unimpaired, it has generally been understood that good results could be obtained by heating the material in a closed container in which a neutral or reducing atmosphere was maintained. It has usually been assumed to be necessary to remove moisture from the gas and in regular mill practice it is dried with concentrated sulphuric acid. For this service commercial hydrogen, dissociated ammonia, producer gas, coke oven gas, and even natural gas have been used. The last two have given indifferent results, although it is possible to operate with coke oven gas which has been carefully purified.

In an investigation conducted at the Schenectady research laboratory a study has been made of the effect on hot steel strip of gas mixtures obtained by the combustion of hydrocarbon-containing gases in a deficiency of air. The conditions to be observed in using these gas mixtures have been rigorously investigated. Successful bright annealing has been done in commercial equipment using them, comparable with results obtained by the use of hydrogen or dissociated ammonia.

Gas atmospheres described later were made by burning Schenectady city gas with insufficient air in a refractory tube filled with crushed refractory impregnated with catalyst. All ethylene and oxygen was then removed; methane up to 10% appeared to exert no influence on the surface of the annealed metal other than that of a diluent of the active gases.

The first indications of the complications attending the use of complex gas mixtures for bright annealing came from the use of a gas containing 25% carbon monoxide and 75% hydrogen. The steel strip was heated for several hours at 650° C. (1200° F.) in a quartz tube with this gas flowing through, and at the end of the experiment it was badly etched and had a matte finish. (There could be no question of alternate oxidation and reduction in these experiments, as we were dealing with a strongly reducing atmosphere.) The drier the gas was made, the worse the etch became!

It is a common experience in contact catalysis that the catalyst becomes more active with use and the surface rougher. It has been assumed in this case that the steel is active as a catalyst for several possible reactions between the components of the gas. Two reactions have been studied and the remainder of this paper will deal with this phase of the investigation.

Abstract of paper for Detroit Convention, A.S.S.T.

The important constituents of the gas phase are carbon monoxide, carbon dioxide, hydrogen, and water vapor. The two reactions to be considered among these components are the "producer gas reaction," $2\ CO \rightleftarrows CO_2 + C$, and the "water gas reaction," $CO_2 + H_2 \rightleftarrows CO + H_2O$.

Equilibrium data for these two reactions are as follows, where the concentrations are expressed in atmospheres:

Temperature		Value of Constant K	
		Producer Gas Reaction $K=\frac{[CO]^2}{[CO_2]}$	Water Gas Reaction $K=\frac{[CO][H_2O]}{[CO_2][H_2]}$
Cent.	Fahr.		
450°	842°		0.133
500	932	0.0046	0.200
550	1022		0.282
600	1112	0.087	0.384
650	1202	0.30	0.500
700	1292	0.87	0.637
750	1382	2.40	

If the compositions of the gas do not correspond to equilibrium conditions at the temperature of the experiment, it is possible for these reactions to be responsible for etching the steel. The most important temperature is the maximum temperature used, namely 650° C., since it is well known that reaction rates increase with temperature and hence the reactions would be proceeding most rapidly at the highest temperature used.

We have been able to demonstrate that both of these reactions are responsible for etching. When mixtures are taken in which $(CO)^2 \div (CO_2) = 0.30$ and $(CO)\ (H_2O) \div (CO_2)\ (H_2) = 0.50$, there is no visible change in the appearance of the steel when heated for as long as 15 hr. at any temperature below 650° C. (The gas must be completely freed from unsaturated hydrocarbons and oxygen.)

There are two other reactions to be considered, but these are easier to control. It is necessary to maintain compositions which avoid oxidizing conditions during cooling from 650° down to 300° C. These can be determined from the equilibrium conditions for the reduction of iron oxide by carbon monoxide and hydrogen, respectively:

$$FeO + CO \rightleftarrows Fe + CO_2$$
$$FeO + H_2 \rightleftarrows Fe + H_2O$$

Without going into the experimental work it may be said that CO_2 must not exceed 75% of the CO in the gas atmosphere to avoid oxidation by the first-mentioned reaction. As to the second reaction: Five per cent of water vapor in hydrogen cannot oxidize steel at any temperature above 300° C. (575° F.); in fact, with $(CO_2) \div (CO) = 0.75$ it is possible to work with $(H_2O) \div (H_2) = 0.25$ without oxidizing steel at any temperature below 650° C. Since the carbon oxides, hydrogen and water vapor occur simultaneously in furnace atmospheres, their mutual relationships must be controlled. As the CO_2 to CO ratio goes up, the H_2O to H_2 ratio should be correspondingly lowered.

If all these conditions are met, it is possible to anneal low carbon steel with a wide range of compositions of mixed gases and leave the surface of the sample unchanged.

Role of Moisture

Two photomicrographs at 250 diameters illustrate very clearly the important role played by moisture in these gas mixtures. (They were selected from a large number to be published in the complete paper.) The same gas was used in both these experiments but for one sample it contained 0.18% water vapor, while for the second the moisture content was 2.6% (saturated at 22° C.). In the first case the water gas constant was 0.019, while in the latter it was 0.28. Experiment has shown that if the ratio $(CO)^2 \div (CO_2)$ be less than about 0.40, the ratio $(CO)\ (H_2O) \div (CO_2)\ (H_2)$ may be made as low as 0.06 to 0.07 before etching begins. In these photographs the parallel lines are roll marks and the black patches in the left micro are pits caused by catalytic activity in promoting the "producer gas reaction" and the "water gas reaction."

A considerable body of experiments have been performed to justify the conclusions, and the results will be given in tabular form when the full text is published in *Transactions*. Many of the successful gas mixtures are non-explosive when mixed with air in any proportion. The $(CO)^2 \div (CO_2)$ ratio falls naturally into a value less than 0.35 when city gas is burned with 2, 2½, or 3 parts of air and cleaned of ethylene

and oxygen. The moisture can then be easily adjusted so the water gas reaction constant lies in the range 1.0 to 0.06, and the gas will not oxidize steel when annealing or cooling. These conclusions have been successfully demonstrated in a commercial installation for bright annealing low carbon steel.

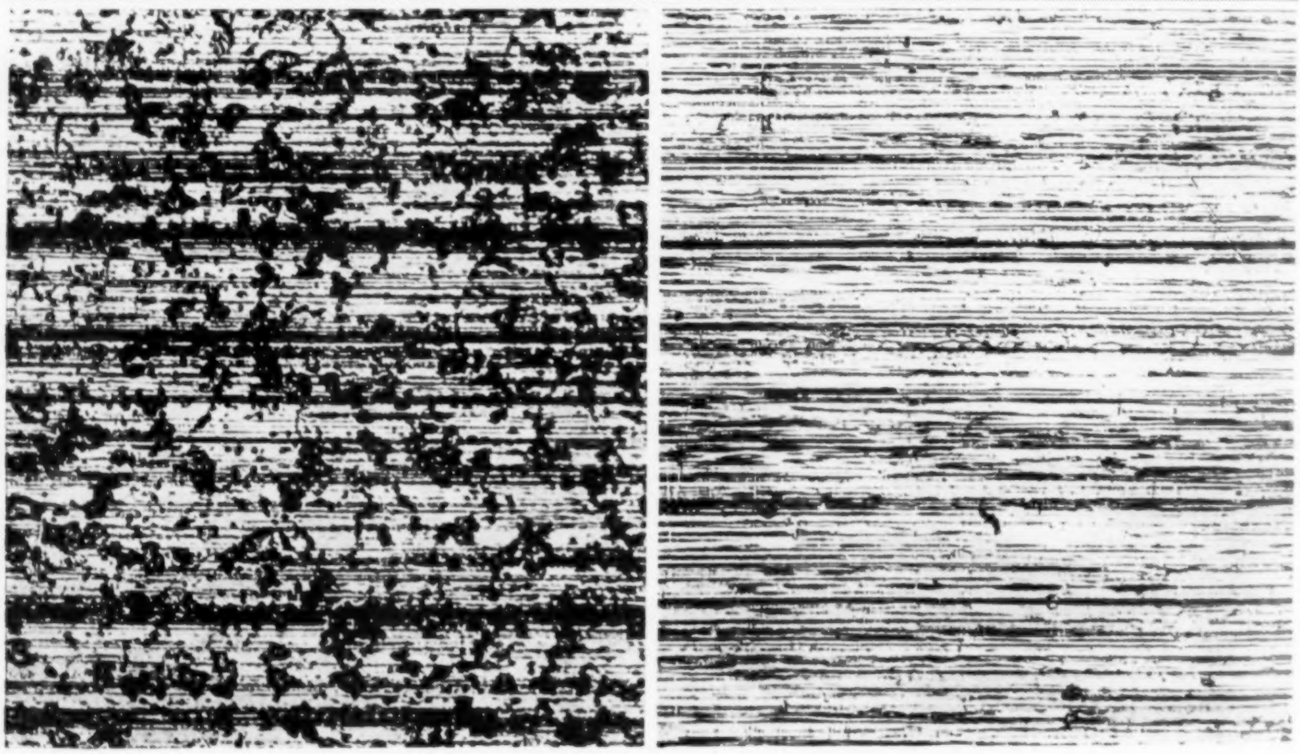
Etching Effect of Gas Mixture

In summary, it may be said that complex gas mixtures containing carbon monoxide, carbon dioxide, hydrogen, and water vapor will etch low carbon steel at 650° C. (1200° F.) unless the compositions are maintained within certain limits. The reactions responsible for etching, when it occurs, are the producer gas reaction and the water gas reaction.

It is possible to anneal low carbon steel with hydrogen containing 20% water vapor without any appearance of oxidation on cooling the sample slowly from the annealing temperature to room temperature.

With gas mixtures containing CO, CO_2, N_2, and less than 0.75% H_2, the ratio $(CO)^2 \div (CO_2)$ can be increased to about 30 before etching starts to appear. When about 6% hydrogen is present, the sample etches badly with a ratio $(CO)^2 \div (CO_2) = 2.6$.

With the ratio $(CO)^2 \div (CO_2)$ kept at 0.40 or less, the value of $(CO)(H_2O) \div (CO_2)(H_2O)$ can be varied from 1.0 to 0.06 without any appearance of etching. When the latter ratio falls to 0.02 the sample starts to etch badly. With the value of $(CO)(H_2O) \div (CO_2)(H_2)$ maintained at 0.50 the ratio $(CO)^2 \div (CO_2)$ cannot exceed 0.50 if the sample is to be annealed to 650° C. without etching.



Cold Rolled Steel Strip After Annealing at 650° C., Magnified 250 Diameters.

Analysis: CO_2 4.8%
CO 10.0
H_2 19.6
H_2O 0.18
$(CO)^2 \div (CO_2) = 0.21$
$(CO)(H_2O) \div (CO_2)(H_2) = 0.019$
Light Etch

Analysis: CO_2 4.8%
CO 10.0
H_2 19.6
H_2O 2.6
$(CO)^2 \div (CO_2) = 0.21$
$(CO)(H_2O) \div (CO_2)(H_2) = 0.28$

By Garnet Phillips, Metallurgist, Frank Foundries Corp., Moline, Ill.

MELTING METHODS FOR ALLOY IRONS

ALLOY gray irons have been produced by the Frank Foundries since 1919. During the ensuing 14 years the technique of production in all its phases has been gradually improved and refined.

Nickel was used in some of the metal first produced, primarily for assuring machinability of castings with higher physical properties. Today a variety of alloy irons is made which may be classed according to the alloying elements used, as follows: (1) Nickel, (2) chromium, (3) nickel-chromium, (4) nickel-copper-chromium, (5) nickel-chromium-molybdenum, (6) nickel-molybdenum, and (7) molybdenum.

Alloy irons now made may also be subdivided into three other groups according to the total carbon content. The first group, which is produced by cupola melting of metal mixtures containing steel, has a range of 3.20 to 3.35% total carbon. The second group, which we usually melt in an electric arc furnace, has a total carbon range of from 2.50 to 3.00%. The third group, which contains the majority of the irons with over 20% alloy, is also melted in the arc furnace and has a total carbon content of less than 2.50%.

In order to indicate the widespread use of the various alloy irons, a list of common applications in several industries may be given—by no means a complete catalog. The automotive industry uses alloy castings for clutch pressure plates, brake drums, sleeves and cylinder liners, and exhaust manifolds. Pumps installed in refrigeration units absorb cylinders, connecting rods, and pistons of alloy iron. Heat treatment of steel and alloy parts in hundreds of scattered plants depends on high alloy heat resisting castings for conveyor chain links, annealing pots, carburizing pots, lead pot grids, and hearths. Pig molds for casting machines handling blast furnace metal are another outlet in the metallurgical industries. Oil and gas burners, both domestic and industrial, use cylinders, collars, disks, and flame spreaders of special irons. At other places in boiler plants we find tuyeres, fuel conveyors, coal plungers, and clinker grinder points. Even in farm implements, where costs are figured very closely, cylinder liners, brake drums, and gears of alloy iron will give most for the dollar.

Some of the properties required in the above-mentioned castings are wear resistance, pressure resistance, abrasion resistance, heat resistance, high strength both at ordinary and elevated temperatures, and ability to harden on quenching. Fortunately, not all of these are required simultaneously, but any of them are beyond the range of common gray iron.

In order to produce alloy irons consistently of uniform physical properties, it is necessary to have a controlled melting procedure which is strictly adhered to at all times.

The greater portion of our tonnage is melted in the cupola. Its operation has been

standardized with the following objects in mind: (*a*) To produce metal at the highest temperature possible — over 2800° F., (*b*) to hold oxidation losses to a minimum, and (*c*) to keep operating conditions uniform, so that very little carbon and sulphur are picked up during melting and the pick-up is low and as nearly constant as possible.

Starting at the beginning, one must control the raw materials. We make every effort to secure high quality and uniformity. Byproduct coke is used, purchased from reliable sources only. It meets and surpasses the standard A.S.T.M. specifications for foundry coke, has good strength to resist crushing, burns rapidly. By its use we are able to produce cupola melted metal at a temperature of about 2830° F. consistently, with low sulphur and carbon increases during melting. It has not been necessary for us to resort to combustibility tests to achieve these ends.

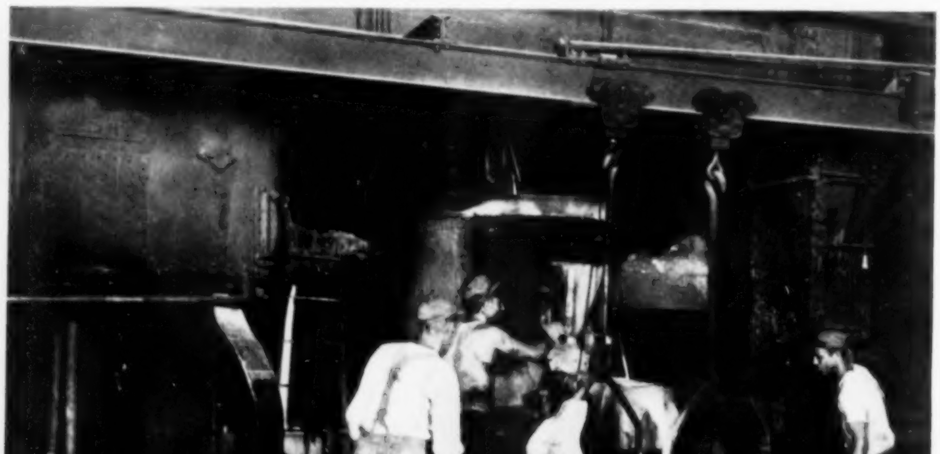
Pig irons are held to close limits in chemical analysis. Sulphur, phosphorus, and manganese are held to standard A.S.T.M. specifications, but silicon is given special attention. Ten pigs from each car are selected at random, sampled, and analyzed individually. Our specification calls for a maximum allowable variation of 0.125% silicon for any class of pig iron. This means that each pig in a car load of about 50 tons must have a silicon content — in the case of a 3.60% silicon iron — within the range 3.48 to 3.72%. (This may seem a narrow range, but we have never had much difficulty in getting it — in fact, we expect to narrow the range to plus or minus 0.075%, since that seems to be readily obtainable. In general, the closer silicon specification merely means that the furnaces segregate their production into a large number of lots, instead of mixing cast after cast into one huge pile.) This method of checking pig iron was started some three or four years ago after considerable trouble was traced to pig irons of widely varying composition in a single car load.

We have thoroughly tried charcoal pig, special low phosphorus, copper-free pig and similar types. An excellent series of tests was made on sleeve castings which were machined and burst hydrostatically. No advantage of any kind was found for these special irons during a test using as high as 35% charcoal iron in the metal mixtures for a period of about two weeks.

No purchased or "foreign" scrap is used in the mixture for alloy iron. Investigation of various classes showed that variations in composition were too large for our use. As an example, 41 scrap automobile cylinder blocks (usually considered first class, low phosphorus material) were analyzed by our laboratory about two years ago, and the following ranges of composition were found: Silicon 2.73 to 1.79%, carbon 3.68 to 2.91%, sulphur 0.145 to 0.071%, phosphorus 0.312 to 0.099%, manganese 1.00 to 0.44%, nickel zero up to 0.57%, and chromium zero up to 0.24%.

What scrap iron is used is provided by sprues and other scrap from our own foundry, both from alloy and gray iron castings. Our gray iron is made from metal charges containing purchased scrap and a comparatively high percentage of pig iron, but the analysis is under close

Cupola Melts Continuously, the Skimmed Iron Being Collected in a Covered Forehearth From Which Metal Is Tapped When Occasion Warrants. Alloying elements are dropped into the stream from the little hopper



control of the metallurgical department.

Fluxing materials are limestone and fused sodium carbonate; both are over 95% pure.

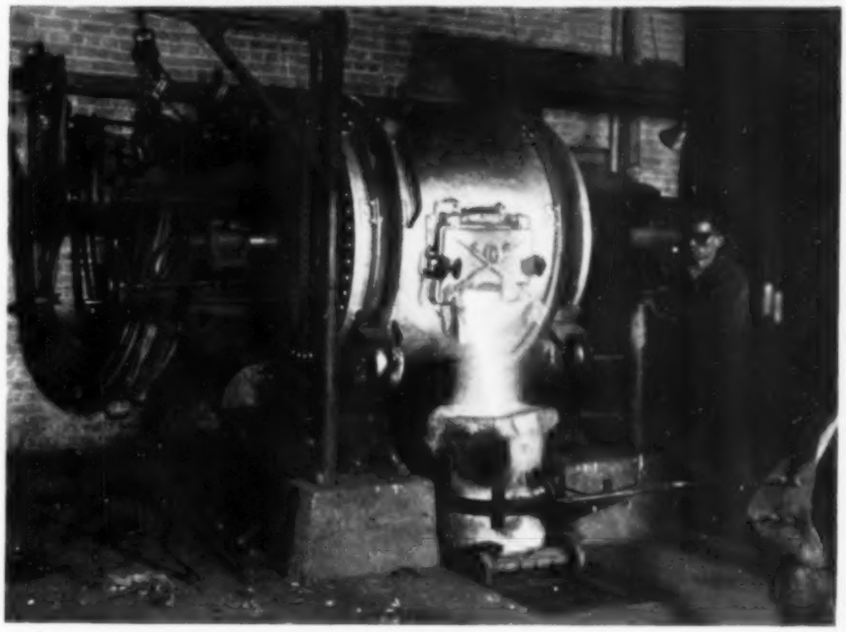
While the present article has to do primarily with melting methods, it is pertinent to remark that scientific control must also extend to the foundry floor. Daily tests are made on sand heaps for moisture, permeability, and bond strength. At intervals fineness tests are run and seacoal content determined. Sand must not be too dry or too wet, must be sufficiently permeable, and have a bond strength above a specified minimum — the values are standardized for the various classes of castings. In general, we use the minimum amount of moisture, the maximum permeability consistent with finish desired, and the lowest practical bond strength. All molds, in general, particularly on production work, are rammed, squeezed, or jolted extremely hard. All new sands are tested for moisture, permeability, bond and fineness.

At present a 60-in. inside diameter cupola is being used to melt iron at the rate of about 9.0 tons per hr. Speaking generally, it may be said that the sole aim of our efforts is to produce uniform cupola metal consistently.

After the bottom is put in and a wood fire lighted, bed coke is filled in up to the top of the tuyeres. This is burned through completely; then the bed is brought up to 50 in. above the top of the tuyeres and charging started. After the cupola is charged, the blast is immediately put on and the heat begun.

Charges weigh 1500 lb., of which 43% is scrap, 35% is pig iron, and 22% steel rails cut to 24 in. Coke used per charge is about 15% by weight of the metal charge, or 224 lb. Air is held at 6100 to 6300 cu.ft. per min. (including all leaks about the cupola) and is held at constant volume throughout the day. Pressure in the wind box is 7 to 8½ oz. Limestone per charge weighs 70 lb.; one cake of sodium carbonate (2.2 lb.) is also added.

The special feature of our melting is a stationary receiving ladle or forehearth which receives the melted metal coming continuously from the cupola. Slag passes off from the



Electric Furnace Is Used Principally for High Alloy, Low Carbon Castings

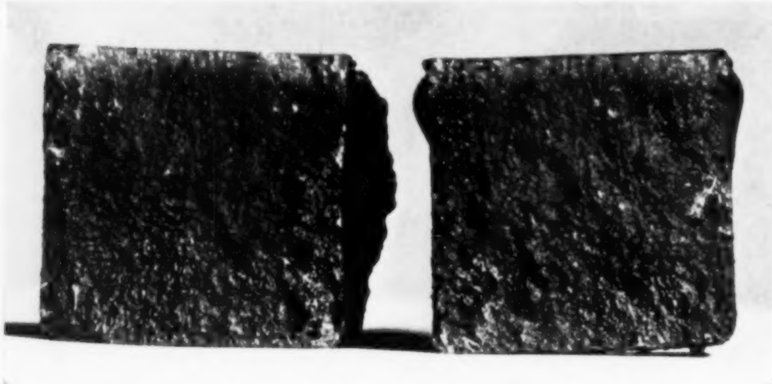
cupola through a slag spout in the usual manner; clean molten iron passes under a trap or skimming spout and flows into the forehearth. The color of the cupola slag is a good indication of melting condition. A light gray color, with a slight greenish tinge shows that oxidation of iron is at a minimum.

One cake of sodium carbonate (2.2 lb.) is added to the stream about as often as a charge is made at the top, so a fluid bath of alkaline slag covers and desulphurizes the accumulated metal. No auxiliary heat is used except at the start of the day, when an oil torch is used to bring the lining to a bright red heat.

The forehearth has a steel cover, brick lined, with a central opening 12 in. square through which all fumes are carried out of the building by a smokestack.

The metal loses from 40 to 55° F. in temperature in the forehearth and is tapped out as desired by the molders at about 2780° F., whereupon the alloys are added in the following manner: A funnel is suspended over the forehearth spout through which are slowly added to the stream of iron weighed amounts of the various alloys, such as nickel shot, ferrosilicon, ferromanganese, ferrochromium, or ferromolybdenum, to produce one ladle of alloy of the composition desired.

Quick control and inspection tests are made



Fracture of 1½-In. Square Bar Cast Against Chill Is Used to Control Total as Well as Combined Carbon

by catching a small ladle of metal from the stream as it passes into the forehearth, and pouring chill test bars and step-bars. The chill depth and appearance of the fracture enable the experienced operator to detect any appreciable variations in composition of the non-alloyed metal. Control of carbon content of this metal is all-important, since the carbon — other things being constant — largely determines strength, hardness, machinability, and shrinkage. Our laboratory runs rapid carbon analyses while the heat is being run on samples from the first of the cupola heat, from the middle, and from the last. A minimum carbon content has been set as well as a maximum. If the analyses show variations from standard, the metal mixture is changed so that the carbon content of the metal charge entering the cupola is raised or lowered, as the case may be, a sufficient amount. This practice, along with the standardized cupola operation, has largely eliminated scrap losses due to shrinkage and hardness.

After the alloyed metal is tapped into ladles, test bars are poured for strength tests, chemical analysis, and examination of fracture. About one set of test bars is poured for each 3 tons of iron melted. They are illustrated and described at length later in this article. On certain castings (such as brake drums, Knight engine sleeves, and cylinder liners) a set of test bars is poured from each ladle of metal. Such castings are all dated and serially numbered. A checker notes the serial numbers of the castings poured with each ladle so that a permanent record is obtained for each casting of the metal composition and strength of bars. If a ladle of metal is found to miss the specifications, the castings poured with it are scrapped.

Control Test Bars

Three test bars are used for rapid control of composition of cupola and alloy iron — a chilled bar, a wedge test bar, and a step test bar. Examples photographed herewith are made of cupola melted iron No. 3 of the table on page 41.

The first bar, which has been longest in use on cupola alloy iron, is a chill test bar 1.5 in. square by 6 in. long, and is cast against a 2-in. iron chill. The fracture illustrated shows the following: White iron at top, $\frac{3}{32}$ in. thick; a layer of mottled iron next, $\frac{3}{16}$ in. thick; then fine gray fracture for $\frac{5}{8}$ in.; the balance is slightly coarser gray iron. This bar is allowed to cool to dull red before taking it out of the mold and water cooling, and is not as rapid as the two bars described later. Measurements are taken from the chilled face inwards, the average thickness of the area being estimated. Only one bar is cast to a chill, to avoid heating the latter. In addition to obtaining the depth of chill, the comparatively wide gray fracture also permits an estimation of total carbon, since the fineness of the outer portion of this gray area is somewhat proportional to carbon content.

The next bar is a "wedge" test bar which, triangular in cross-section, is cast vertically in a baked oil-sand core with the big end up. The bar is taken from the core immediately after

Wedge Bar Cast Vertically in Core to Control Electric Furnace Iron

solidification, the big end water cooled to black; then the base of the triangular section is water cooled to black. The pointed edge, which chills, cools in air. This bar is quickly made and fractured and is used principally to control electric furnace irons. The fracture illustrated shows white iron $\frac{5}{32}$ in., mottled $\frac{3}{16}$ in., and the balance gray. The measurements are made across the bar at the widest point of the area being measured.

The step bar is molded in a green sand drag with a cover core for a cope. Seven patterns are mounted on a plate; an individual cover core is placed over each step bar so that one bar may be poured at a time and removed about one minute after pouring. The big end is water cooled while the small end air cools. One view shows the bar re-assembled (it is cast flat side up) and another the ends of the fractures. Fracture of the $\frac{1}{16}$-in. step is all white; the $\frac{1}{8}$-in. step has white edges, the $\frac{1}{4}$-in. and the $\frac{3}{8}$-in. steps are all gray. This step bar is used on electric furnace irons as a further check on the wedge bar, and on cupola irons as a check on "splits" for changes from soft gray irons to alloy irons, or vice versa.

Utility of Electric Furnace

We have an electric arc furnace of the rocking type which is used whenever alloys low in carbon must be produced. Its principal utility is to generate very high temperatures (up to 3100° F.), which will melt irons of any carbon content desired as well as any alloy content. There is, of course, a limit to the amount of cold metal which can be absorbed by iron running out of the cupola forehearth, but the electric furnace can take any alloy in any quantity and maintain it at temperature — while the metal is being tested and analyzed.

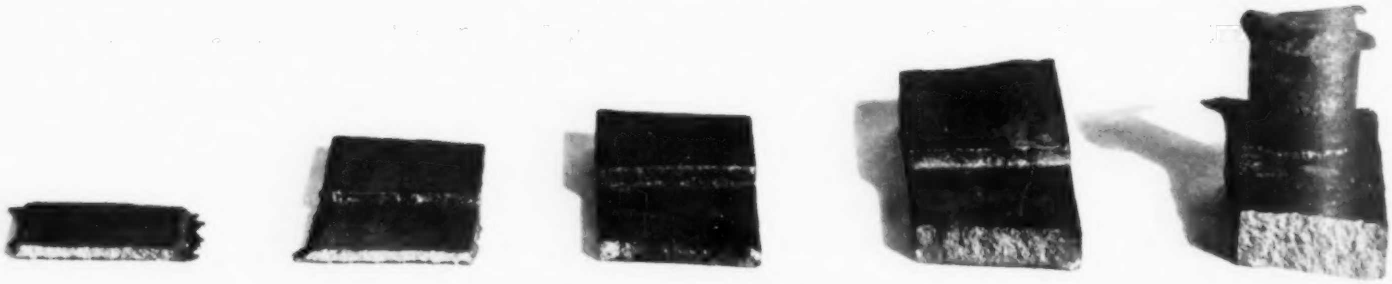
We have not been able to improve our cupola melted alloy irons materially by superheating them in the electric furnace. We believe this is due to the high temperatures reached by the cupola metal in passing through the melting zone. Therefore, the electric furnace is used principally to supplement the cupola by melting irons that are impractical or impossible to produce in the cupola.

Typical examples of the cupola and electric furnace alloy irons produced, with their physical properties, are given in the table on page 41. They indicate the possibilities of the modern foundry in the production of alloy irons. Chemical analyses and hardness tests were made on 1.20-in. diameter transverse test bars 21 in. long. Transverse test bars were broken on supports 18 in. apart, and modulus of rupture and modulus of elasticity calculated from test data at breaking load. Tensile tests were made on standard A.S.T.M. bars machined from the broken transverse bars. Check tests are also frequently made on bars cut from castings. A daily record is made of the pattern numbers or code of all alloy iron castings, together with data as to the base metal used and the amounts of alloys added. This permanent record, kept by the metallurgical department, now dates back seven years, and assures that the correct alloy iron is used for a re-order, no matter how long the casting has been out of production.

Physical Properties

In selecting alloy irons for particular uses from the point of view of strength, it is well to remember that the irons that show high tensile values (as determined by cast test bars made under conditions most favorable for sound specimens free of shrinkage cavities and internal stresses) have high shrinkage, and that the castings poured from them are not always stronger nor as sound as those poured with metal which shows lower tensile strength in the test bars.

As an example, cylindrical castings with a wall thickness of $\frac{3}{8}$ in. as cast, which we produce in large quantities, were tested hydrostatically to failure after finish machining. The castings are machined all over and have a wall thickness of $\frac{1}{8}$ in. and an inside diameter of $4\frac{1}{4}$ in. The bursting pressure ranges from 2700 to 3000 lb. per sq.in., which corresponds to tensile strengths of from 45,900 to 51,000 lb. per sq.in. (computed by the thin-walled pipe formula). Test bars machined from transverse bars of 1.20 in. diameter and cast tensile bars of various diameters from 0.875 to 0.375 in. show tensile strengths of from 37,000 to 45,000 lb. per sq.in., when cast with the same



metal. The same castings poured with metal showing 55,000 to 60,000 lb. per sq.in. tensile strength on test bars, burst at pressures ranging from 1700 to 2700 lb. per sq.in. The lower bursting pressures were in all cases due to shrinkage defects, as the castings are difficult to feed properly during solidification.

In general, we have found excellent agreement in the tensile strength of cast tensile test bars and test bars cut from castings poured with alloy irons with tensile strengths in the range from 35,000 to 55,000 lb. per sq.in. This agreement, of course, depends in large measure on gating and risering — in other words, on the ability of the foundryman to produce sound castings.

Castings of widely varying metal sections may be produced with uniform hardness and other physical properties when they are cast of a proper alloy iron with low total carbon. As an example of the uniformity of hardness obtainable, Brinell hardness tests across the diameter of a cross-section of a 5½-in. solid cylinder, 12 in. long, may be quoted as follows: Edge 255, 255, 241, center 248, 241, 255, edge 255. The ¾-in. sprue used to pour the cylinder had a hardness of 248. The chemical analysis made on drillings taken from the center of the cylinder corresponded to electric furnace iron No. 18 (table on page opposite) except that nickel was up to 1.70%.

The use of alloy irons has shown a steady, consistent growth. Cupola alloy irons have supplemented and broadened the field of non-alloyed irons. The newer electric furnace alloy irons still further broaden the fields of application of cast irons.

It is hoped that the data presented in this article will give the members of the various engineering professions who use alloy irons a better understanding of the production methods, properties, and possibilities of this material.

Fractured and Re-assembled Step Test Bar Used to Check Results of Wedge Bar and for Information When Analysis of Cupola Iron Is Changed at Mid-Heat

Chemical and Physical Properties of Alloy Cast Irons

Line No.	Chemical Analysis										Transverse Bars				Tensile Strength	Hardness		Line No.
	Silicon	Carbon	Graphite	Combined Carbon	Sulphur	Phosphorus	Manganese	Nickel	Chromium	Molybdenum	Load Pounds	Deflection Inches	Modulus of Elasticity Lb. per Sq. In.	Modulus of Rupture Lb. per Sq. In.	Lb. per Sq. In.	Brinell	Rockwell "B"	
Typical Examples of Cupola Melted Alloy Irons																		
1	1.90	3.25	2.67	0.58	0.096	0.240	0.59	0.53	0.17		2760	0.32	10,300,000	73,300	36,440	207	94.5	1
2	1.97	3.24	2.67	0.57	0.098	0.242	0.58	0.79	0.31		2880	0.33	10,100,000	76,500	37,520	207	94.0	2
3	1.94	3.28	2.64	0.64	0.094	0.252	0.56	1.46	0.58		2860	0.28	12,200,000	75,800	37,660	217	97.0	3
4	2.05	3.29	2.64	0.65	0.072	0.229	0.62	1.26	0.61		2660	0.28	11,300,000	70,500	40,000	207	93.5	4
5	2.04	3.30	2.60	0.70	0.091	0.239	0.61	1.28	0.74		2860	0.29	11,800,000	75,800	41,160	212	94.0	5
6	1.94	3.20	2.20	1.00	0.091	0.196	0.63	1.54	1.14		2880	0.25	13,800,000	76,500	42,260	255	100.2	6
7	1.90	3.25	2.48	0.77	0.096	0.240	0.59	0.81	0.17	0.75	3260	0.31	12,500,000	86,500	47,300	241	101.5	7
8	1.74	3.16	2.46	0.70	0.053	0.189	0.68	1.06	0.21	0.77	3430	0.34	12,000,000	91,000	51,900	223	94.5	8
9	2.09	3.28	—	—	0.088	0.227	0.65	1.08	0.73	0.50	2970	0.27	13,100,000	88,700	38,140	223	100.0	9
10	1.40	3.18	2.41	0.77	0.047	0.210	0.46	1.40	0.32	1.20	4000	0.46	10,400,000	106,300	57,340	241	100.7	10
11	1.85	3.37	2.66	0.71	0.058	0.180	0.57	1.58	0.42	1.25	3600	0.45	9,500,000	95,500	53,080	311	106.7	11
12	1.96	3.14	2.41	0.73	0.053	0.173	0.62	1.52	0.13	1.18	3760	0.39	11,500,000	99,500	55,520	241	99.5	12
Typical Examples of Electrically Melted Alloy Irons																		
1	1.86	3.32	2.48	0.84	0.045	0.221	0.62	1.42	0.55	0.50	2840	0.27	12,500,000	75,200	47,400	248	101.0	1
2	1.92	3.13	2.34	0.79	0.060	0.269	0.71	1.62	0.53	0.50	2800	0.22	15,200,000	74,300	50,600	262	102.7	2
3	2.75	2.35	2.01	0.34	0.028	0.106	0.53	29.80	2.56	0.67	3230	0.48	8,000,000	85,700	49,300	212	95.5	3
4	2.32	2.31	2.18	0.13	0.034	0.088	0.38	35.20	0.76	0.75	1280	0.45	3,400,000	33,900	17,500	81	56.0	4
5	2.29	2.51	1.89	0.62	0.032	0.199	0.59	0.78	0.02	0.17	2630	0.20	12,500,000	69,700	43,650	248	99.0	5
6	2.17	2.70	2.13	0.57	0.069	0.174	0.55	1.29	0.21	0.75	3430	0.25	16,400,000	91,000	58,720	293	105.0	6
7	2.03	3.10	2.32	0.78	0.045	0.208	0.50	1.36	0.22	0.49	3000	0.27	13,300,000	79,500	48,000	241	102.2	7
8	2.51	2.46	1.87	0.59	0.027	0.089	0.57	1.10	0.04	0.50	3250	0.23	16,900,000	86,100	63,510	321	108.7	8
9	1.75	3.05	2.16	0.89	0.030	0.152	0.82	1.54	0.62	0.50	3000	0.22	16,300,000	79,500	55,550	286	106.0	9
10A*	2.85	2.70	2.70	—	0.073	0.170	0.53	1.48	0.24	0.50	2880	0.24	14,300,000	76,300	46,100	170	87.2	10A
11	2.16	3.21	2.54	0.67	0.050	0.255	0.57	1.38	0.36	0.50	3160	0.29	13,000,000	83,700	53,000	255	102.0	11
12	1.94	3.15	2.49	0.66	0.023	0.047	0.47	1.24	0.14	0.48	3130	0.33	11,300,000	83,000	60,200	269	102.0	12
13	3.13	2.72	2.08	0.64	0.024	0.047	0.48	0.92	0.26	0.47	2920	0.23	15,200,000	77,500	55,460	277	103.0	13
14	1.88	2.97	—	—	0.067	0.153	0.62	1.58	0.28	—	3000	0.27	13,200,000	79,500	54,800	277	105.0	14
15A*	1.96	1.84	—	1.84	0.057	0.032	0.65	0.42	23.95‡	—	4285	0.19	26,900,000	113,600	85,600	341	108.2	15A
16	2.11	3.07	1.77	1.30	0.031	0.034	0.25	1.10	—	0.98	3400	0.26	15,600,000	90,000	55,860	286	105.0	16
17†	1.85	2.42	1.43	0.99	0.061	0.156	1.09	13.20†	1.70	—	2700	0.40	8,100,000	71,500	35,440	163	88.5	17
18	2.58	2.67	2.01	0.66	0.084	0.176	0.54	1.22	0.21	—	2900	0.27	12,800,000	77,000	43,580	241	98.5	18
19	1.18	1.57	—	1.57	—	—	0.31	—	24.70‡	—	4670	0.23	24,200,000	124,000	73,800	363	C-39.5	19

* 10A is completely annealed and 15A is annealed

† Iron 17 was produced under license granted by International Nickel Co.; this analysis also contained 5.50% Copper

‡ Irons 15A and 19 were produced under license granted by Electro Metallurgical Co

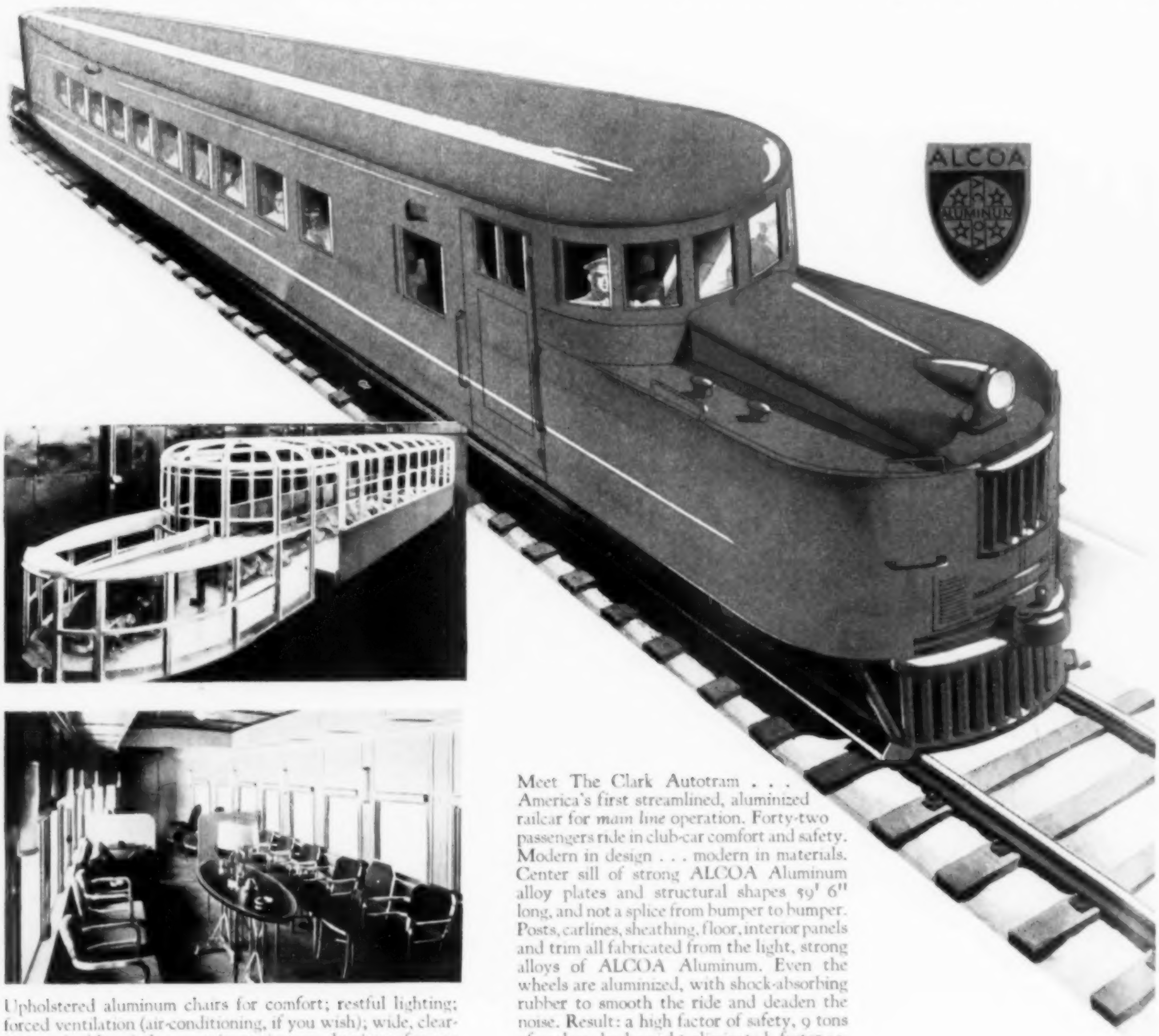
Data by Garnet Phillips, Metallurgist,
Frank Foundries Corporation, Moline, Ill

ALCOA *Aluminum*

SPEEDS the wheels of Transportation

Speed and more speed, with *safety*, comfort and economy—that's what the transportation industry wants today. And that's just what the alloys of ALCOA Aluminum offer. Here's the metal with the strength of structural steel, yet only one-third the weight. The metal that lops off tons of dead weight, cuts power and maintenance costs, permits swift starts and quick stops, lets the engine pull heavier loads at higher speeds or the same load at less cost. Above all, properly designed aluminum cars are safe. This light weight, high strength metal permits building cars with an increased factor of safety and ability to withstand shock.

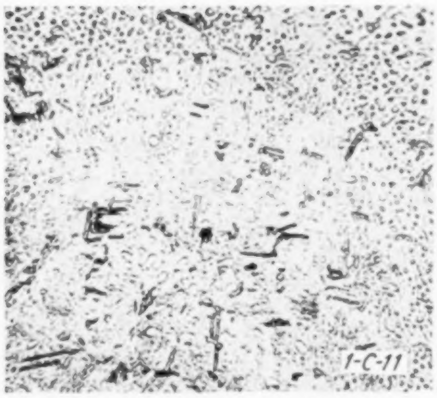
Not only in railroading, but in street cars, motor buses, mine cars, truck bodies, overhead cranes, factory trucks—wherever mass is in motion—ALCOA Aluminum alloys cut down mass and speed up motion, with safety.

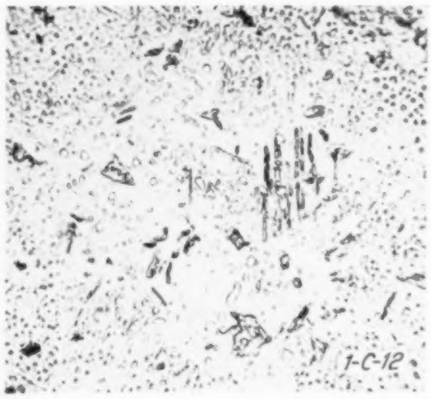


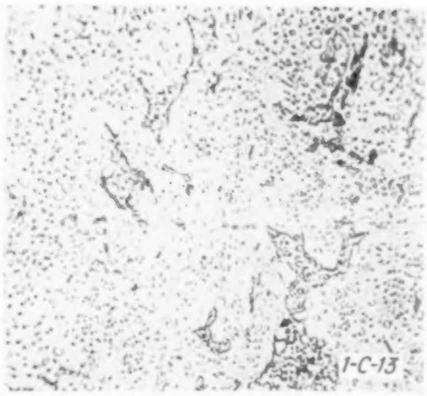
Upholstered aluminum chairs for comfort; restful lighting; forced ventilation (air-conditioning, if you wish); wide, clear-vision, double windows set in stationary, aluminum frames; inside panes shatterproof. All the comforts of home, thanks to the many forms and shapes of ALCOA Aluminum alloys used for interior trim, fittings and furnishings.

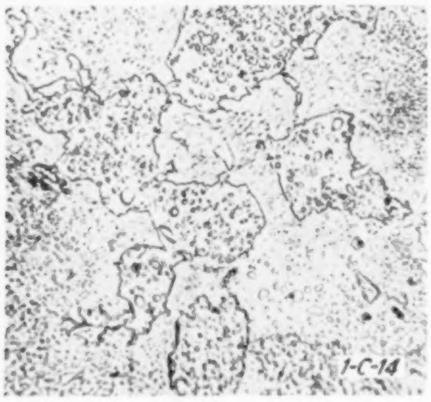
Meet The Clark Autotram . . . America's first streamlined, aluminized railcar for *main line* operation. Forty-two passengers ride in club-car comfort and safety. Modern in design . . . modern in materials. Center sill of strong ALCOA Aluminum alloy plates and structural shapes 59' 6" long, and not a splice from bumper to bumper. Posts, carlines, sheathing, floor, interior panels and trim all fabricated from the light, strong alloys of ALCOA Aluminum. Even the wheels are aluminized, with shock-absorbing rubber to smooth the ride and deaden the noise. Result: a high factor of safety, 9 tons of useless dead-weight eliminated, faster acceleration, quicker stops, lower power costs, less maintenance of equipment and track.

Martensite with Ferrite and Pearlite

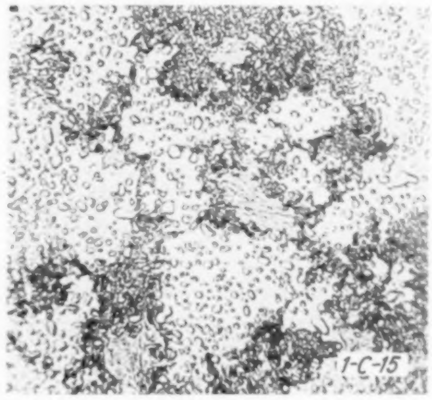




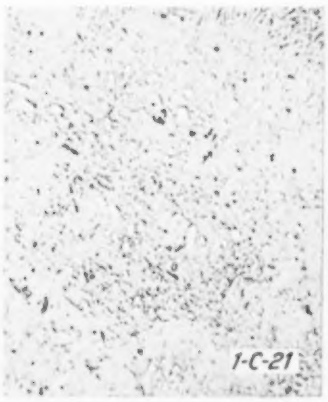


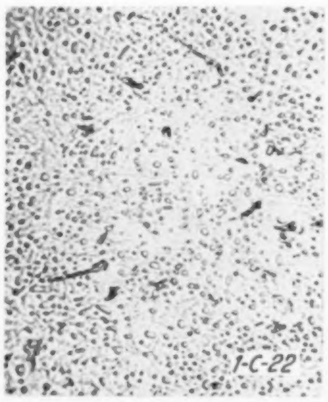


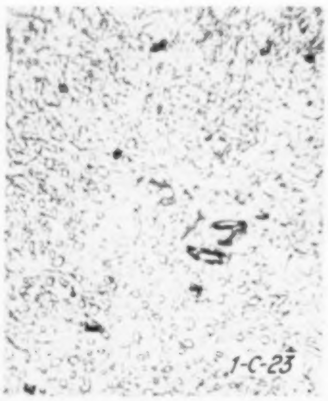
Micros 1-C-11 to 1-C-15 at 1000 diameters. Granular pearlite (or ferrite) was undissolved when the pieces were heated; structures are obtained by quenching medium-small pieces of 1% carbon steel from 760 to 790° C. (1400 to 1450° F.) after holding varying times at quenching temperature

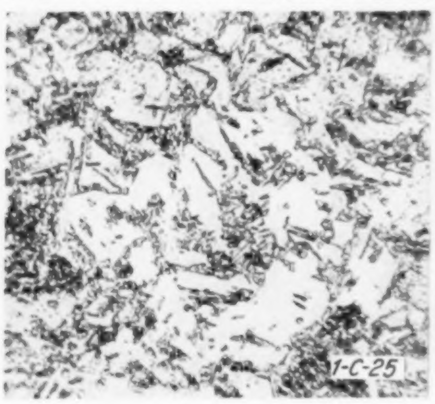


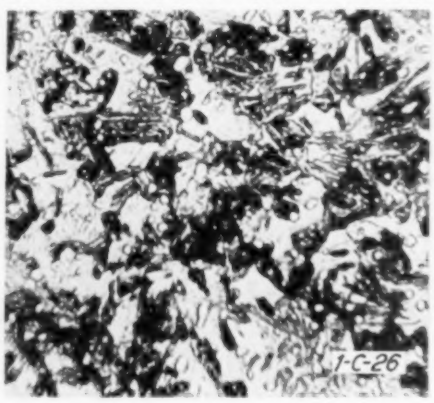
Martensite and Undissolved Pearlite (or Ferrite)

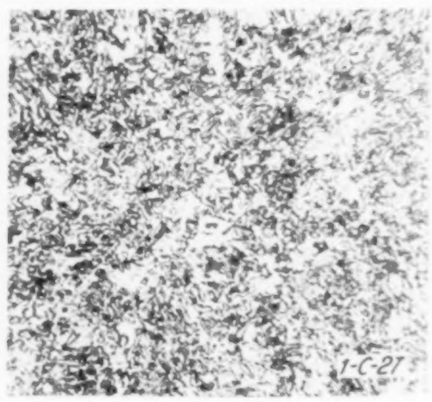












Martensite and Precipitated Ferrite

Structures are produced by cooling rates, while quenching, too slow for complete formation of martensite. Quantity of secondary ferrite usually increases inward from surface (or somewhat below). All micros made by SKF Research Laboratory, at 1000 dia., etched with 1% nital

correspondence

Nitrided Cast Iron Cylinder Liners

TURIN, ITALY — A rational application of knowledge recently acquired about the nitriding of steel (noted in my May letter to METAL PROGRESS) has solved the problem of nitriding cast iron. Its practical importance is confirmed by the excellent service obtained from different machine parts.

One of the fields where it has given the most excellent results is the manufacture of cylinders and cylinder liners for all types of reciprocating motors and pumps. Several plants devoted exclusively to the manufacture of such cylinders are now in operation or under erection in France and Italy. By far the greatest part of the production is cylinder liners for internal combustion engines.

As the first requirement for obtaining a good nitrided iron free from superficial brittleness, is to reach the greatest possible dispersion of both the ferrite and graphite in the microstructure, it is evident that the casting and heat treating conditions have a paramount influence on the quality of the product and its performance in service.

In the special case of cylinder liners, the best results have been obtained by centrifugal casting, followed (after rough machining) by air hardening from about 1725° F. and reheating to produce a Brinell hardness in the soft core varying from 255 and 320, according to the size and form of the piece.

The metal generally used is a chromium-aluminum iron, having approximately the following composition: Total carbon from 2.40 to 2.80%, silicon from 2.40 to 2.80%, manganese from 0.50 to 0.70%, chromium from 1.30 to 1.70%, aluminum from 0.60 to 0.80%, sulphur and phosphorus each less than 0.07%. This iron is melted in a revolving furnace and poured very hot in a small ladle which contains the correct amount of aluminum.

The inner surface of the cylinders is finish machined and the external surface is protected against nitriding. The pieces are then nitrided at a temperature of 950 to 970° F. Experience has proved that a temperature slightly higher than that generally used for nitriding steel — 930° F. — gives better results, especially in reducing the brittleness of the outer layers.

When an iron of the above-mentioned composition is nitrided for 60 to 70 hr., a surface hardness of 900 to 950 Brinell-Vickers is obtained. The nitrided layer is about 0.016 in. thick. After nitriding at 985° F. for the same time, the hardened layer is 0.004 to 0.008 in. thicker, but the surface hardness is reduced to 700 to 750 Brinell-Vickers.

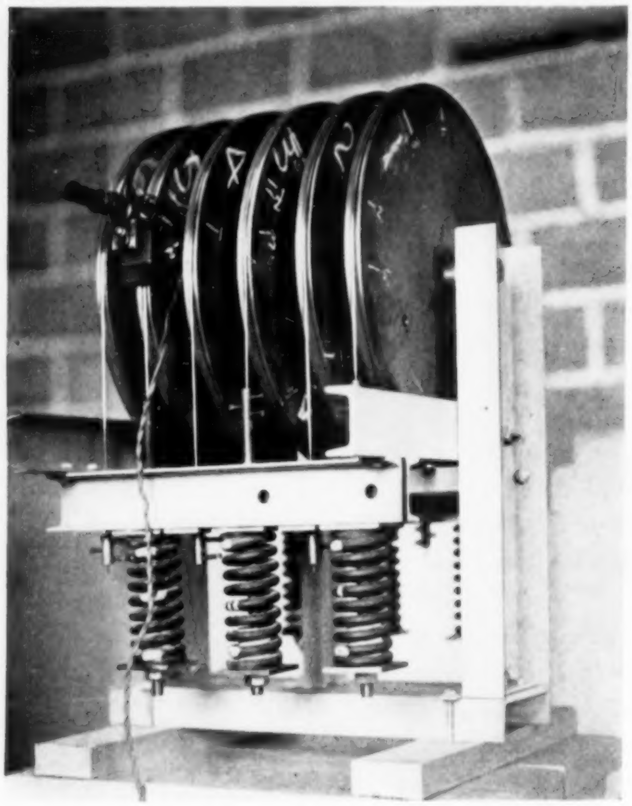
It would take too much space to quote a sufficient number of data to review the practical results obtained with nitrided cylinders. One illustration must suffice: The motor of a touring car had three cylinders equipped with nickel-chromium steel linings, heat treated to Brinell hardness of 400; the three others were of the above-described nitrided iron. After running 22,000 miles the nickel-chromium iron cylinders were oval by 0.0059 in. while the wear of the nitrided cylinders was less than 0.0004 in. It is only natural that under these conditions the oil consumption is greatly reduced by the use of nitrided cylinders.

FEDERICO GIOLITTI

Heat Treated Wire Tested Under Steady Load

URBANA, ILL. — During the past year, F. W. Gartner has carried out a preliminary series of tests at University of Illinois under the writer's direction on heat treated eutectoid steel wire (not galvanized). This note is given publicity at this time as further work will probably go slowly, on account of lack of funds. The results are merely preliminary, but in the wire tested it seemed very difficult to get anything approaching a spreading crack.

The wire tested was in two forms and was furnished by a manufacturer of spring wire. One was bare 0.040-in. strip with a yield point of 182,000 (load necessary for 0.75% elongation) and ultimate strength of 235,500 lb. per sq.in. (slightly stronger than round galvanized bridge wire). The other was 1/8-in. wire slightly weaker than the above.



Machine for Loading Round Wire Specimens

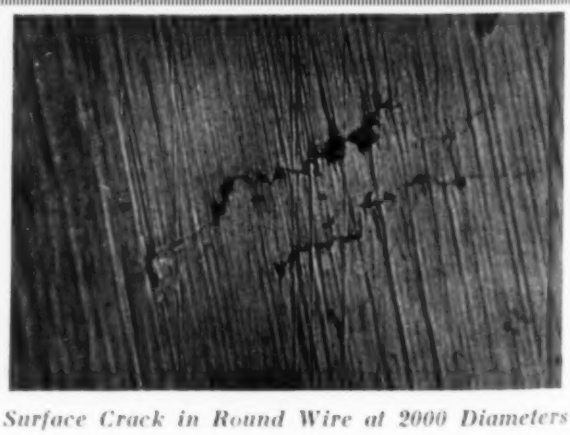
Testing equipment for long time tests under steady load is shown in the illustration. For the strip the sheaves were 5½ in. diameter, and for the wire 20 in. These diameters were so chosen, because the elongation of the outer fiber of the wire, bent around them, was the same as the elongation at the "Johnson elastic limit," taken from the stress-strain curve of a tension test. From this point on, the stress was increased by the calibrated spring to whatever was desired. To aid in microscopic examination of the samples (at 50 diameters) all the specimens under test were polished down to FFF emery dust on oil-soaked felt.

Four of the twelve specimens tested were very carefully preformed so the loop hung snug to the sheaves. Exact diameter of mandrel and necessary length of wire were found by trial and error. The others were merely placed around the sheave and drawn up. One-third of the samples had the entire direct load (ranging from 8000 to 50,000 lb. per sq.in.) added immediately; the others (including the preformed specimens) were loaded by increments at 12-hr intervals, and thus simulated the creeping load occurring during the erection of a suspension bridge. All specimens were explored by microscope, and suspicious markings (about eight per specimen) were recorded and re-examined at intervals of one to three days.

No breakages have occurred (three of the specimens are still under load) and the only mark to develop into an unmistable crack in these twelve specimens was on one of the round wires, not preformed, loaded with 30,000 lb. per sq.in. by calibrated spring at time of mounting, and this load not changed. The crack was not observed to be present at the time of loading, but appeared to grow with time, although dulling of the polished surface made estimation difficult. After the load had rested 47 days, the wire was dismounted and examined at high power; a true crack was found; other suspicious markings proved to be corrosion effects or surface blemishes. The microstructure was fine sorbite, and numerous fine inclusions were scattered about.

It is believed that this crack was not in the wire when mounted, but it evidently could not be due to a creeping load or incorrect preforming as the test load was quiescent and the wire was not preformed. A slight blemish or slag inclusion may have been an important factor in the starting of the crack, but it must be remembered that a perfect surface is a commercial impossibility.

H. F. Moore
Professor of Engineering Materials



Surface Crack in Round Wire at 2000 Diameters

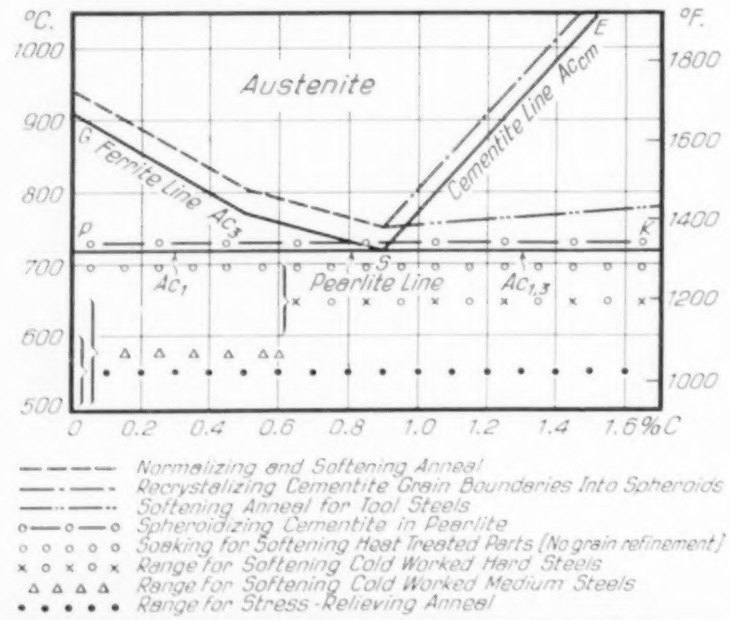
correspondence

Annealing Diagram

BERLIN, GERMANY — Readers of METAL PROGRESS may be interested in a modification of the iron-carbon equilibrium diagram which shows the temperatures at which carbon steels should be annealed. This diagram was published a few months ago in *Maschinenbau*, and has been well received for its practical value.

It is to be noted that the temperatures for normalizing and for softening anneal of hypo-eutectoid steels are the same. The operations, of course, have different objects in view. Normalizing, as performed in Germany, is intended to (*a*) produce a fine grain and homogeneity, prerequisite for other heat treatments or for machinability, (*b*) to give certain desired tensile properties, or (*c*) to recrystallize cold worked steel. A softening anneal, on the other hand, is to eliminate forging structure (as before case hardening), to recrystallize, or to soften. Heating in both cases should be no longer than to complete the solid solution. Cooling for normalizing is in air; for a softening anneal it should be no faster than 35° F. per hr. down to 1200° F. (the slower, the softer the steel will be); below that it may be more rapid. Combination treatment, normalizing followed by annealing for nodular cementite, gives the softest and most ductile hypo-eutectoid steel.

Temperatures Suitable for Various Annealing Operations



High carbon steels do not usually need normalizing above line *S-E*, unless they have been somewhat overheated. Cooling should then be in air. If the cementite network does not exist, steels can be softened by reheating above line *S-K*. Air cooling in either case may produce sorbite, difficult to machine, and this can be corrected by reducing the cooling rate or by reannealing just below line *S-K*. (Sorbite also frequently exists in tool steel bars, as rolled.) Normalizing, followed by a softening anneal, frequently results in improved strength, elongation, and hardening structure.

Best machinability of many tool steels is had when three-quarters of the cementite is nodular, and the remainder is in fine lamellar pearlite. For such structure the steel may be more or less completely spheroidized by soaking just above the critical, as shown in the diagram, then reheating briefly slightly higher to redissolve the correct amount of carbide, and then cooling in the furnace at the correct rate for fine pearlite (about 35° F. per hr.).

Soaking for softening a hardened steel requires up to several hours, depending on composition and dimensions. Furnace cooling is to be preferred. Long time at heat tends to spheroidize the cementite in the pearlite.

Temperature and duration of the softening anneal for cold worked metal depend on the amount of working, the desired properties, and the bulk of the metal.

ADALBERT JUNG

Interrupted Hardening of Spring Wire

MELBOURNE, AUSTRALIA — After reading Dr. Diergarten's article and Dartrey Lewis's letter on the interrupted hardening of steel. I decided to make a few simple experiments along the same lines.

The first was to quench two 12-in. lengths of spring wire, 0.256 in. diameter, from 1500° F., one in cold oil, the other in a salt bath heated to 450° F., where the wire was held for 30 sec. before it was allowed to cool in air. On removal

correspondence

from the salt, the wire was soft enough to bend with comparative ease, holding each end in a pair of tongs.

As soon as the piece quenched in salt was cold enough to be handled, the diamond pyramid hardness of both pieces was measured by means of a Firth Hardometer. In both wires it was 834.

Later I made a second experiment but was obliged to use wire from another coil. The wire in the first case analyzed C 0.84%, Mn 0.68%, Si 0.28%, P 0.05%, and S 0.03%. In the second the carbon was 0.77 but otherwise it had a very similar analysis.

The results of the second trial are as follows: Quenched from 1500° F. into salt at 450° F., held 1 min. and cooled in air: 512 Brinell; held 1 min. and cooled in water: 719 diamond pyramid; held 5 min. and cooled in air: 512 Brinell; held 5 min. and cooled in water: 587 diamond pyramid; quenched in cold oil from 1500° F.: 834 diamond pyramid.

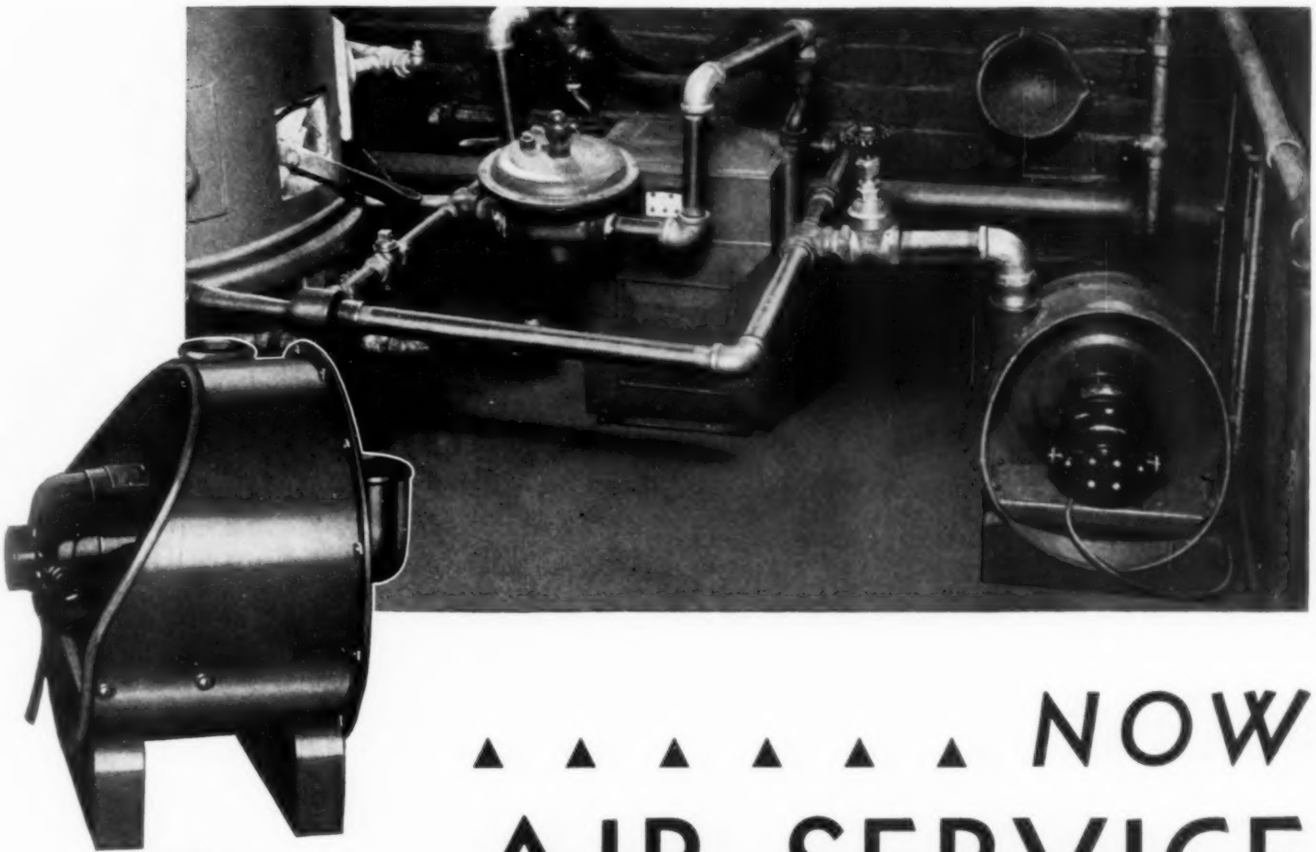
I might add that these soft quenched and air cooled wires became hard before they were cold enough to be touched with the hands. The water-cooled ones were hard when taken from the water.

HAMILTON FERGUSON

Metallurgical Use of Calcium Phosphate

GROSNY, U.S.S.R. — Ten years ago an enormous body of phosphate rock was discovered in the tundras north of the Arctic Circle, near our most northerly seaport Murmansk. Since then about 50,000,000 tons have been blocked out, and about 250,000 tons yearly are being mined for treatment.

The "ore" contains three chief minerals, apatite or calcium phosphate, nepheline or alkaline alumino-silicate, and titano-magnetite. It analyzes from 22 to 32% P_2O_5. It is ground and passed through flotation cells, after which the apatite concentrate (40% P_2O_5) is changed



chemically into fertilizer or exported for a similar purpose.

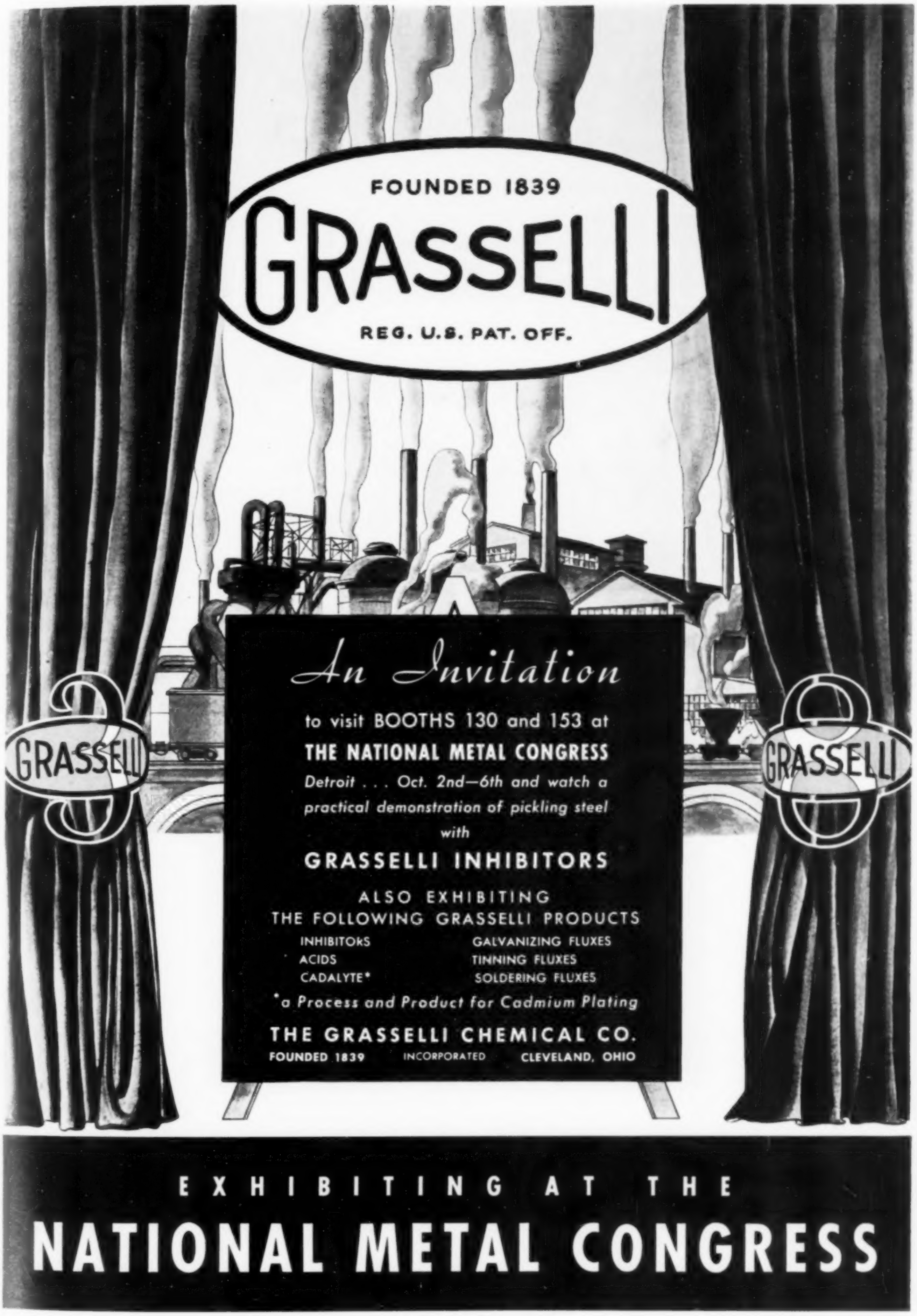
Several interesting experiments have been made with the raw ore and concentrates in an effort to replace imported ferrophosphorus or other alloys. For instance, it was charged in a cupola with low phosphorus pig iron, and the phosphorus in the melted metal was doubled. No bad effects on the lining were noticed, and the slag was fusible and liquid, even though but little limestone was used on the burden. It is planned to mix it with the blast furnace charge in order to produce high phosphorus pig iron in places where only low phosphorus iron ore is available.

High phosphorus steel has been produced with phosphate rock at the Baltic Shipyards (Leningrad) both in electric and open-hearth furnaces. A small electric furnace melted a ton of ship plate scrap with 110 lb. of apatite. A cast of high grade metal analyzing 0.31% carbon, 0.05% silicon, 0.40% manganese, 0.38% phosphorus, and 0.065% sulphur was produced.

A second heat was then made in a 7-ton acid open-hearth furnace. During the boiling period two charges of apatite concentrate were made; with the second 65 lb. of ferrosilicon was introduced to aid in the reduction, together with some sand to flux the calcium oxide. After refining and adding ferromanganese the metal was normal, and cast after 6 hr. 15 min. Analysis was 0.14% carbon, 0.21% silicon, 0.41% manganese, 0.29% phosphorus, and 0.02% sulphur.

Such material is favored by our engineers for such things as nuts, and in the past it has been produced by adding some 40 lb. of imported ferrophosphorus per ton of steel. It would appear that equally good results can be had with calcium phosphate.

Comparative tests have also been made in the non-ferrous foundries in Leningrad. Crucible-melted ingots of bronze, deoxidized with the crushed ore, were compared with others treated with phosphor copper. In both cases the metal was sound and suitable for the intended purpose. In another foundry, which uses a ½-ton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electric furnace, melts of brass and bronze are made under a blanket of apatite ore. A little phosphorus is reduced and enters the metal, which in turn removes oxygen, and the thick layer of slag minimizes vaporization losses (2.5% instead of 9% as formerly).

B. M. SUSLOV

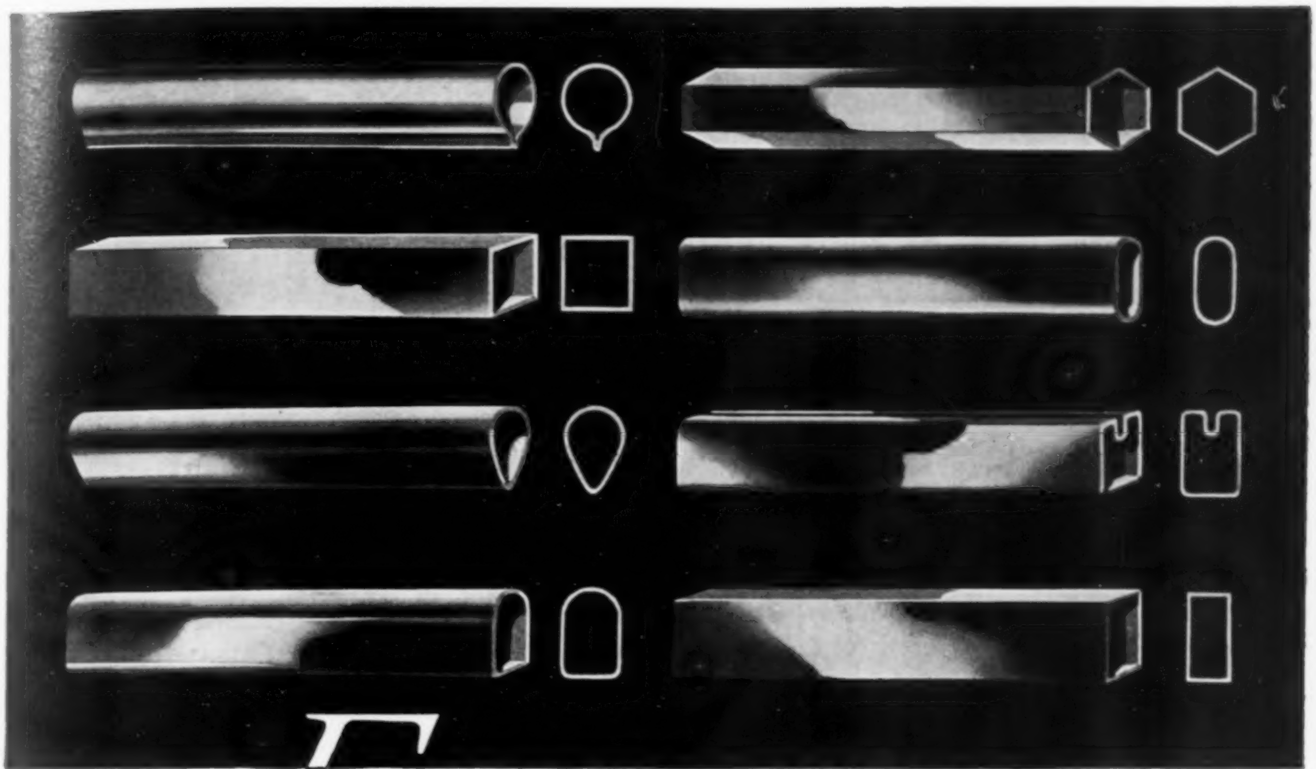
Light Metals in Germany

SCHWEINFURT, GERMANY — A two-thirds reduction of the dead weight is, of course, the fundamental cause of the widening use of light metals in machine construction. Further impetus to the use of the hardenable aluminum alloys came after the expiration, at the beginning of 1932, of the patents for duralumin owned by the Dürener Metal Works.

The year 1909, in which Alfred Wilm discovered precipitation hardening, as well as the excellent development work performed by the Dürener Metal Works, will remain as high points in the history of light metals. The word "duralumin" remains legally the property of Dürener, and in addition it has adopted the name "Dürener original duralumin" to mark its product. To those interested in the history of metals, an excellent resume of the commercial development of light metal alloys in Germany is given in *Zeitschrift für Metallkunde*, January, 1927, under the title "100 Years of Aluminum."

By cooperative action of the various producers other than Dürener Metal Works, the Vereinigte Leichtmetallwerke G.m.b.H. at Bonn becomes a central bureau, which on the basis of its wide experience, can give advice and information on any problem in the field of light metals. "Bondur" has been placed on the market by this association as an alloy corresponding to duralumin.

The hardening properties of "bondur" are due to the addition of about 2 to 5% Cu, 0.5 to 2.0% Mg; manganese, silicon and iron are present in small amounts. *(Continued on p. 62)*



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As knowledge of ENDURO, Republic's Perfected Stainless Steel, becomes more widespread, its uses in the form of tubing multiply. Industry after industry is finding new uses for tubing made of this life-long metal—where tubing stronger than carbon steel yet lighter in weight is required—where tubing resistant to corrosion in the highest degree is required—where it is necessary to employ tubing that will withstand high temperatures without scaling and that will show high creep strength—where tubing must convey food products and freedom from metallic contamination is a vital consideration—and where chemicals must pass through tubing without change in their composition.

Electrunite Tubing is made by electrical resistance welding of cold formed strip of the correct stainless analysis to meet specific service conditions—ENDURO 18-8 and other chromium-nickel analyses. It is manufactured in a wide range of sizes, shapes and finishes. And the selection of the correct grade of ENDURO is made easy through the wide experience of the metallurgical staff of the world's largest producer of alloy steels.

Descriptive literature will be sent on request.

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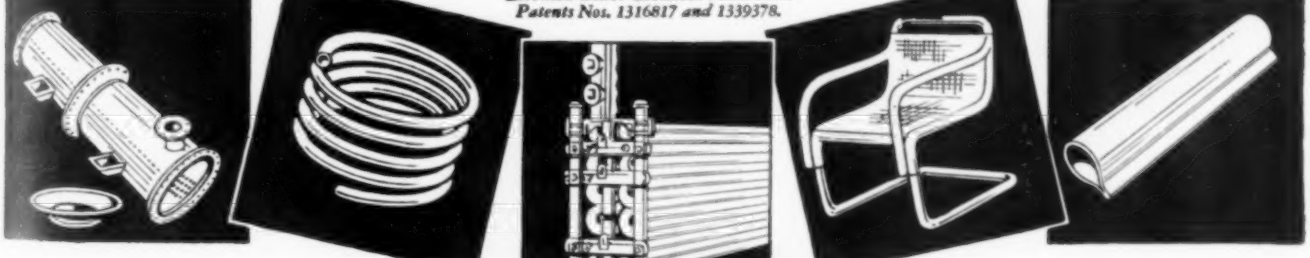

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New Furnace Blowers

Two new types of Turbo-Compressors are described in recent publications of Spencer Turbine Co. Uses for the ⅓ hp. Turbo are presented, as is a description of the new single stage Turbo-Compressor which affords tremendous economies in low pressure gas and oil fired equipment. Bulletin Sp-70.

Aluminum vs. Corrosion

In the carefully prepared booklet, "Combating Chemical Corrosion with Alcoa Aluminum," published by Aluminum Co. of America, effects of various corrosive agents upon aluminum and its alloys are described in detail. It is an excellent and convenient source of information on this subject. Bulletin Sp-54.

Hardness Testing

Everyone interested in the testing of metals for hardness will do well to have on hand a copy of a catalog recently issued by Wilson Mechanical Instrument Co., illustrating and describing the latest design of Rockwell Hardness Testers and auxiliary work supports. Bulletin Sp-22.

Belt Conveyor Furnaces

Full descriptions and photographs of furnaces for economically heat treating small and medium sized parts are given in an 8-page bulletin covering continuous chain belt conveyor furnaces made by Electric Furnace Co. Over 50 such furnaces are now in operation. Bulletin Sp-30.

Cyanide Baths

Much practical information on the heat treatment of steels with cyanides and salts is contained in a descriptive booklet of E. I. duPont de Nemours & Co., R. & H. Chemicals Dept. The booklet contains many valuable suggestions for improved quality heat treating. Bulletin Sp-29.

Electric Furnaces

Full details of the line of electric furnaces made by Hoskins Mfg. Co. are well presented in their latest 42-page catalog. Contents include description and data on 17 types of furnaces and some valuable information on Chromel resistance wires and thermocouples. Bulletin Sp-24.

New Heat Controller

"Straight Line Control" of furnace temperature is possible with the Trendalizer Controller made by Brown Instrument Co. There is no zig-zagging across the control point, because this unique device changes its control action in accordance with both temperature trend and extent of deviation. Bulletin Sp-3.

Choosing Nickel Steel

International Nickel Co. has an ingenious chart to show at a glance the nickel alloy steel compositions and treatments needed to develop yield points in section sizes from 1 to 12 in. It is useful in selecting bars, shafting and forgings of simple shape. Bulletin Au-45.

New Foxboro Pyrometer

Foxboro Co. describes the new Foxboro potentiometer recording pyrometer in a recent bulletin. The outstanding features are a new design of balancing mechanism, ability to make from one to six records, a 12-in. chart, rapid recording cycle and a moisture-proof case. Bulletin Au-21.

Sheffield Steel

Wm. Jessop & Sons, Inc., in a recent publication explain why their Sheffield Superior oil hardening steel does not distort and is easily machined. They assign as reasons a special anneal and a proper balancing of the carbon, manganese and tungsten contents. Full details are presented in Bulletin Jn-61.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. The information given is complete and authoritative. Bulletin S-27.

X-Rays in Industry

General Electric X-Ray Corp. has available a profusely illustrated brochure entitled "Industrial Application of the X-Ray," which gives the complete story of the field of application of this modern inspection tool. Valuable information is presented. Bulletin Ma-6.

Scleroscopes

The model D standard recording scleroscope is described and illustrated in a recent publication of Shore Instrument Co. The theory and practice of hardness testing with this portable machine as described in this bulletin reveal a fund of valuable facts. Bulletin S-33.

High Cr Cast Iron

A pamphlet describing foundry production of cast irons containing from 15 to 30% of chromium has been issued by Electro Metallurgical Co. These cast irons do not grow or scale after repeated heatings and are excellent for high temperature work. Bulletin Ma-16.

Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Corp. A list of the standard industrial type heating elements and a coordinated list of terminal mountings and accessories is included. Bulletin N-25.

Fatigue Testing

That much discussed topic—fatigue testing—is covered in a publication of Thompson Grinder Co. Interesting data on fatigue of metals and a description of the rotating beam type of fatigue testing machine are presented. Bulletin D-23.

Atmosphere Furnaces

A new folder issued by Surface Combustion Corp. gives performance data on their atmosphere furnaces compiled from installations in actual production. Operations described include bright annealing of ferrous and non-ferrous metals, carburizing, nitriding, forging without scale and hardening without scale. Illustrated. Bulletin Ap-51.

Quicker Heat Treating

Driver-Harris Co. discusses Nichrome sheet containers for heat treating in an illustrated folder which honestly states that while for certain purposes sheet containers cannot be used economically, there are a multitude of installations where their advantages of lightness and quicker heating can be fully utilized. Bulletin Jl-19.

Uses of Molybdenum

Climax Molybdenum Co. offers a new and useful 50-page booklet dealing with the benefits conferred by molybdenum as an alloying element in iron and steel. In orderly fashion engineering data are presented and made clear with numerous tables and illustrations. Bulletin Au-4.

"Vee-less" Arc Welds

New literature covering a very recent development in arc welding has been prepared by Metal & Thermit Corp. Known as Murex Straight Gap welding, the new process eliminates grooving or "veeing" the edges even of heavy plates. Welding time is halved and other savings are effected, it is claimed. Bulletin My-64.

Low Cost Recorder

Inexpensive dependability in measuring and recording temperature is the great asset of the new Leeds & Northrup round chart Micromax indicating recorder which brings the reliability and easy maintenance of the motor-driven null recorder to a new low cost. Bulletin Ap-46.

New Type Furnace

A new bell-type retort furnace made by American Gas Furnace Co. can be used in quick succession for carburizing, nitriding, bright annealing in gas atmospheres, or for hardening, normalizing, tempering or annealing. It is an ideal heat treating tool where production is widely varied in character. Bulletin Jn-11.

New Zinc Coating

Wire which has been zinc coated by the new Bethanizing process is described in Bethlehem Steel Co.'s latest folder. This process produces a zinc coating which has proved to be more ductile, tighter, tougher, more uniform and purer. Coatings 3 times as heavy as formerly can be made. Bulletin Au-76.

Maintenance Welding

This interesting booklet describes the use of the oxyacetylene process in the reclamation of broken and worn machine parts, alteration, fabrication and installation of equipment. Such equipment as piping, tanks, machine elements, engine and pump parts and conveying systems is covered in the 16-page illustrated booklet of Linde Air Products Co. Bulletin Jl-63.

2 Everdur Booklets

Two recent publications of American Brass Co. discuss Everdur, the high strength, corrosion resisting copper alloy. One covers its physical properties and resistance to corrosion, the other tells how to weld it. Either or both will be sent. Bulletins Jl-89a and Jl-89b.

Art of Metallography

Bausch & Lomb Optical Co. offers a 130-page book, "Optical Instruments for Examining Metals," which is a beautifully executed source of information on this subject. The book is at once a convenient reference text on optics, a treatise on photomicrography and a catalog of B. & L. products. Bulletin Jn-35.

Micro-Metallograph

Metallurgists will be interested in the description of the Leitz Model MM-2 Micro-Metallograph. This simplified instrument at low cost provides all essential optical and mechanical equipment to meet the requirements of industry. Bulletin Fe-47.

To Prevent Rust

The well known rust preventive, No-Ox-Id, is now available from Dearborn Chemical Co. as a foundation for paint. It is available in the colors red, gray or black. A booklet explains how maximum resistance to corrosion can be obtained. Bulletin Ju-36.

Quenching Handbook

E. F. Houghton & Co. have published an excellent 80-page handbook on the subject of quenching. More than 30 charts and photomicrographs help tell the story. A copy will be sent free to those who request it. Bulletin Jl-38.

Nitriding Facts

Information on possible new applications of Nitralloy and the nitriding process in view of recent developments may be obtained from Ludlum Steel Co. New economies in production and a better product may now be obtained. Bulletin Jn-94.

Stainless Sheets

A very useful booklet describing the stainless steel sheets and light plates made by American Sheet & Tin Plate Co. gives recommendations for fabrication and a description of finishes and analyses available. Bulletin Ap-96.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in one of that company's publications. Bulletin D-17.

Welding Stainless

An unusual amount of practical data is contained in a fine booklet just put out by Republic Steel Corp. which gives recommendations for welding the several Enduro stainless alloys. Generously illustrated. Bulletin Jn-8.

Roll Grinding

Carborundum Co. has just published a 50-page booklet on roll grinding which may be considered a handbook of available information on this subject. Carefully written and amply illustrated, this treatise will undoubtedly be of real practical value. Bulletin Au-57.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is the usual practice. Bulletin Fe-13.

Pickling Inhibitors

A pamphlet describing the nature and use of Grasselli Inhibitors is available to all those interested in the pickling of steel. It not only describes the merits of these inhibitors, but it gives a table of suggested inhibitor strengths to be used in the pickling of the various grades of steel. Bulletin Ap-95.

METAL PROGRESS,
7016 Euclid Ave., Cleveland.

Please have sent to me without charge the following literature as described in the September issue. (Please order by number only.)

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correspondence

Heat treatment consists of quenching, usually from a salt bath into water, from 490 to 510° C. (about 930° F.) depending on the size of the piece. The alloy must first be thoroughly cold worked by rolling or pressing to destroy the cast structure. The composition quoted for "bondur" is similar to a typical "duralumin" of Dürener Metal Works, namely about 4% Cu, 0.5% Mg, and 0.5% Mn, together with the iron and silicon derived from the aluminum ingot.

"Bondur" has a tensile strength of 57,000 to 64,000 lb. per sq.in. and an elastic limit of 40,000 to 42,500 lb. per sq.in., with elongation of 23 to 16% in the quenched and aged condition. In the quenched and cold worked condition the values are 62,500 to 70,000 lb. per sq.in. tensile strength and 50,000 to 65,000 lb. per sq.in. elastic limit, with 15 to 2% elongation depending upon the amount of cold work. Brinell hardness of 125 to 150 is attainable. It is practically non-magnetic. In impact strength, fatigue limit, and corrosion resistance, "bondur" fills the highest requirements which can be placed today on light metals.

General physical data are as follows for temperatures up to 100° C.:

Specific Gravity	2.8 grams per cu.cm.
Annealing temperature	350° C. (662° F.)
Forging temperature	450° C. (842° F.)
Quenching temperature	500° C. (932° F.)
Freezing point	650° C. (1202° F.)
Modulus of elasticity	10,000,000 lb. per sq.in.
Coefficient of expansion	0.000023 per °C.
Specific heat	0.214 calories per gram per °C.
Latent heat of fusion	100 calories per gram
Thermal conductivity	0.35 in c.g.s. units
Electrical resistivity	5 microhms per cu.cm.

It is noteworthy that neither tensile nor impact strength is adversely affected at low temperatures; on the contrary, these values are increased. Tensile strength and elongation of 60,000 lb. and 22% of a typical aged alloy when tested at room temperature increase to 62,100 and 23% respectively when tested at −150° F. These properties make the material particularly applicable to aircraft construction.

HANS DIERGARTEN